SIMULTANEOUS EQUATIONS SYSTEM ESTIMATION: AN APPLICATION IN THE CATTLE - BEEF SECTOR

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ABSTRACT

SIMULTANEOUS EQUATIONS SYSTEM ESTIMATION: AN APPLICATION IN THE CATTLE-BEEF SECTOR

by

Samuel Galen Unger

The underlying problem to which this thesis is addressed is broadly a need for improved knowledge of basic economic interrelationships between producer segments of the agricultural economy and the marketing and consumer segments of the general economy. This study focuses principally on interrelationships within the cattle-beef sector of the economy; but account is taken of other sectors by incorporating economic relationships of the cattle-beef sector in a simultaneous equations system framework.

Aggregative United States beef cattle producers' behavior is postulated as consisting of three parts: production for slaughter, production retained (inventory) for feeding purposes, and production retained for non-feeding purposes; and three corresponding behavioral relationships are specified. Marketing firms' composite behavior is treated analytically as a single aggregative marketing segment equation; and consumers' behavior is summarized analytically in a specified retail beef demand equation. A similar set of equations is

specified to explicitly incorporate behavioral relationships of an aggregated other livestock-meat sector; and finally two identities are specified to complete the system of equations.

Several alternative statistical estimation procedures are used to obtain estimates of parameters in the specified structural equations of the model. Namely, the procedures employed are Ordinary Least Squares (OLS), Two-Stage Least Squares (2SLS), Unbiased Nagar K-Class (UNK), Limited Information Single Equation (LISE), Three-Stage Least Squares (3SLS), and Iterative Three-Stage Least Squares (I3SLS). These alternative sets of estimates are presented and compared; and the 3SLS (beginning with 2SLS) estimates are evaluated in further detail.

The equations of the model were fit using United States annual time series data for a sample period from 1936-41, 1949-63. All data used were secondary, primarily from the records of federal government departments and agencies; although some data series were transformed to meet the special needs of this study.

Major findings include a structural form elasticity of slaughter beef supply with respect to current average farm price of -.137. A further analysis of the producer-segment relationships led to similar elasticities of +.1127 and +.3284 for 3-year and 5-year adjustment horizons, respectively. Statistically significant (and different) coefficient estimates

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TABLE OF CONTENTS

Chapter		Page

LIST OF TABLES

Table		Page

LIST OF FIGURES

Figure		Page

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Relationships in the aggregate cattle-beef sector in the United States and interrelationships of this sector with other economically related sectors are specified and estimated in this study. The relationships postulated are treated as a system of simultaneous equations and alternative estimators are employed for obtaining the structural form parameter estimates. It is believed that a simultaneous equations system approach to economic analysis of the cattle-beef sector is a practical and useful method for discovering and measuring the extent of the interdependent nature of some nationally important economic variables and relationships.

The underlying problem to which this study is addressed is the need for increased knowledge of some of the basic interrelationships among the producer segments of the agricultural economy, and the marketing and consumer segments of the general economy. Basic relationships within the cattle-beef sector in particular have been difficult for researchers to formulate accurately and estimate from time series data.

A major contention in this study is that beef cattle producers' supply response, price relationships arising from marketing firms' behavior, and consumers' behavior are sufficiently jointly related so that procedures which analytically treat the corresponding behavioral relationships simultaneously can be usefully employed. Economic models are, of course, subjective formulations; but they are based upon economic theory, a knowledge of the sectors being studied, and various institutional constraints placed on the system. Evaluation of the estimated relationships in an economic model is likewise subjective; however, the burden of the "proof" rests with the analyst and only after proper evaluation can any one approach to the underlying problem be regarded as useful for understanding and explaining basic economic relationships.

Objectives

The main aim of this study is to investigate the endogenous mechanism of the cattle-beef sector by first prescribing an economic model to represent the endogenous mechanism and then fitting the model using simultaneous equations estimation methods. Ultimately, in a study of this kind, the researcher usually has the purposes of predicting future values of economic variables and of predicting the consequences of various proposed economic policies. The results of this analysis will be used to some extent for such prediction purposes.

In addition to the main objective of the study there is also a set of intermediate or "working" objectives which were derived in order to more effectively approach a successful completion of the main objective. Implicitly, the researcher trusts that the discipline of fulfilling the intermediate objectives leads to fulfillment of the principal aim and the ultimate purposes of prediction. The intermediate objectives are described as follows:

(1) To postulate a set of relationships within the cattle-beef sector (and the other livestock-meat sector) which meaningfully represent the aggregate behavior of beef cattle producers, marketing firms, and consumers;

(2) To estimate parameters, both structural form and reduced form, which will contribute to a better understanding of these economic interrelationships, particularly those within the cattle-beef sector of the general economy;

(3) To employ alternative simultaneous equations estimation methods, compare estimates from the alternative estimation procedures, and ascertain the apparent advantages of any particular estimation method;

(4) To utilize and relate the results of other analyses in this area when formulating and evaluating the fitted relationships;

(5) To explore alternative specifications of the relationships postulated with the belief that valid improvements may be discovered (model construction is unquestionably a subjective process and an investigator's initial specifications may not be the most suited formulation of the model); and

(6) To utilize and evaluate the reduced form coefficient estimates in the final model as a means for predicting changes in various economic variables.

Methodology

Six alternative estimators are used for estimating the structural form parameters of the specified relationships in this study;[1] and they will be referred to as Ordinary Least Squares (OLS),[2] Two-Stage Least Squares (2SLS),[3] Unbiased Nagar K-Class (UNK),[4] Limited Information Single Equation (LISE),[5] Three-Stage Least Squares (3SLS),[6] and Interative Three-Stage Least Squares (I3SLS).[7]

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[1]These estimators (except I3SLS) have been discussed in the literature so no attempt will be made to detail their development here. The assumptions and the statistical properties of the paramater estimates depend on the estimation method used, however; and these aspects of the estimators will be discussed in the statistical model section of Chapter III.

[2]See, for example: Johnston, J.: Econometric Methods, New York: McGraw-Hill, 1963, Chapter IV; and Goldberger, A. S.: Econometric Theory, New York: John Wiley and Sons, 1964, Chapter IV.

[3]Theil, H.: Economic Forecasts and Policy, Amsterdam: North Holland (second revised edition), 1961; and Basmann, R. L.: "A Generalized Classical Method of Linear Estimation of Coefficients in a Structural Equation," Econometrica, Vol. 25, January 1957.

[4]Nagar, A. L.: "The Bias and Moment Matrix of the General K-Class Estimators of the Parameters in Simultaneous Equations," Econometrica, Vol. 27, October 1959.

[5]Anderson, T. W. and Rubin, H.: "Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations," Annals of Mathematical Statistics, Vol. 20, March 1949; and Koopmans, T. C. and Hood, W. C.: "The Estimation of Simultaneous Linear Economic Relationships," in Studies in Econometric Method, Cowles Commission Monograph No. 14, W. C. Hood and T. C. Koopmans, editors, New York: John Wiley and Sons, 1953, Chapter VI; and Chernoff, H. and Divinsky, N.: "The Computation of Maximum Likelihood Estimates of Linear Structural Equations," in Studies in Econometric Method, Cowles Commission Monograph No. 14, W. C. Hood and T. C. Koopmans, editors, New York: John Wiley and Sons, 1953, Chapter X.

[6,7]See following page.

The OLS method is strictly a single equation technique which does not account for a particular equation being embedded in a system. Theoretically, this method will be unsuited for all but one of the relationships in this analysis, but it will be used for all the equations for comparative purposes.[8] OLS estimation has been the most widely used method in agricultural economic research to date; and because relatively little is known about the small sample characteristics of the other estimators, there seems to be a general interest (and usefulness) in presenting the OLS estimates in addition to the others.

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[6]Zellner, A. and Theil, H.: "Three-Stage Least Squares: Simultaneous Estimation of Simultaneous Equations," Econometrica, Vol. 30, January 1962; and Rothenberg, T. and Leenders, C. T.: "Efficient Estimation of Simultaneous Equation Systems," Econometrica, Vol. 32, January 1964.

[7]Iterative Three-Stage Least Squares refers to a procedure which successively utilizes the (N-1)-Stage Least Squares parameter estimates in order to derive the (N)-Stage Least Squares estimates. This procedure is a logical extension of 3SLS. William Ruble, who programmed this procedure for Michigan State University's CDC 3600 computer system, has termed the procedure I3SLS; and his forthcoming Ph.D. thesis will include the computational details of this estimator (and the other estimators used herein). Further, he has planned to investigate the theoretical properties of this estimator; so, anticipating the "appropriate" theoretical basis for this procedure, I3SLS estimators are included in this study for "future" interpretation.

[8]A theoretical problem arises with OLS estimation if more than one endogenous (jointly dependent) variable is specified in an equation. The problem arises because the endogenous variables are generally considered to be correlated with the disturbance (random error) term. In such cases the parameter estimates are said to be biased and inconsistent. OLS estimation is considered strictly applicable when only one dependent (endogenous) variable is specified as a function of independent (predetermined) variables.

The 2SLS, UNK, and LISE methods are also single equation estimation methods, but in each case the method takes limited account of the equation being embedded in a system. In this sense, these estimators are simultaneous equations estimation methods.

Another general classification by which each of the first four estimators can usefully be described is that each is a (k)-class estimator.[9] For the OLS and 2SLS methods the k-values are known constants, namely $k = 0$ in OLS estimation (hence, it is a trivial case), and $k = 1$ in 2 SLS.

The k-values for the UNK and LISE procedures have to be determined for each of the single equations to be fitted, however. In the UNK method, Nagar has proposed that the k-value should be calculated as $k = 1 + \frac{L-1}{T}$, where L is the number of predetermined variables in excess of the number of coefficients to be estimated and where T is the number of observations.[10] Nagar shows that this k-value can be expected to reduce a small sample bias of 2SLS (to the order of T^{-1}) in most simultaneous equations studies. (Alternative k-values have been proposed by Nagar, but they are not included in this study). For the LISE procedure, the k-values will always be greater than one for over-identified equations (and equal to one for just identified equations). In one context, the k-value is derived in a manner such that it corresponds to a minimum ratio of residual variances, i.e., the

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[9]Theil, H.: op.cit., 1961, pp. 231-237.

[10]Nagar, A. L.: op.cit., 1959.

residual variance from regressing a linear combination of the endogenous variables on the predetermined variables in the equation, divided by the residual variance of the same linear combination of the endogenous variables regressed on all the predetermined variables in the system.[11] In another context, the k-value also corresponds to a minimum characteristic root of a determinantal equation.[12]

Turning to the 3SLS method, this estimator is generally referred to as a simultaneous equations system method since the parameters of all the identified structural equations are estimated simultaneously. This method also makes use of restrictions on the parameters of the full system in estimating each structural equation and in this sense 3SLS is also termed a "full-information" method.[13] The 3SLS method was developed by Zellner and Theil in 1962.[14]

The 3SLS method requires initial estimates of the coefficient parameters and the disturbance covariance matrix in order to

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[11] For a more complete account of this interpretation, see Hildreth, C. and Jarrett, F. G.: A Statistical Study of Livestock Production and Marketing, Cowles Commission Monograph No. 15, New York: John Wiley and Sons, 1955, p. 69; and Koopmans, T. C. and Hood, W. C.: op.cit., pp. 166-177.

[12] For an account of this derivation, see, for example, Goldberger, A. S.: op.cit., pp. 340-341.

[13] For a concise summary of the characteristics of system methods of structural estimation see Goldberger, A. S.: op.cit., 1964, pp. 346-356.

[14] Zellner, A. and Theil, H.: op.cit., 1962.

obtain estimates in the "third-stage" of this method. Zellner and Theil have shown that the 3SLS method is expected to be more efficient than 2SLS, and they recommend that the 2SLS estimates be used as the starting estimates for 3SLS.

A logical extension of the 3SLS procedure is to establish an iterative process by successively utilizing the (N - 1)-Stage Least Squares (e.g., 3SLS) estimates in order to derive (N)-Stage Least Squares estimates (e.g., 4SLS). Zellner and Theil refer to this procedure as a possibility in their concluding remarks: "One can set up a new stage based on this estimator (3SLS). . . and proceed iteratively."[15] Pending further theoretical development they did not conjecture any further expected advantage from employing such a procedure.

Despite the lack of an appropriate theoretical foundation for proceeding with the above mentioned iterative scheme, such estimates will be presented and the method referred to as Iterative Three-Stage Least Squares (I3SLS). The main reason for doing so is strictly intuitive at this time;[16] namely, given that 3SLS estimates are "more accurate" than 2SLS estimates, then re-application of the same method using the "more accurate" estimates as starting estimates would reasonably seem to support the

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[15] Ibid., p. 77.

[16] Also, the marginal cost of obtaining I3SLS estimates was reasonably low with the computing routines and facilities available.

procedure. Application of the I3SLS method is admittedly an experiment and a "tangent" analysis in this study, but future research and development in this area may disclose its applicability in simultaneous equations studies of this kind.

This selection of estimators does not exhaust the currently known alternative procedures for fitting simultaneous equations. Other known systems methods include Full-Information Maximum Likelihood, or more generally, the Full-Information Least Generalized Residual Variance method; and Linearized Maximum Likelihood, which is another version of the generalized method.[17] Because computer routines were not yet available at the time of this study, no further attempt was made to include the other known estimation procedures.[18]

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[17] The Full-Information Least Generalized Residual Variance method was developed by the following authors: Koopmans, T. C.; Rubin, H.; and Leipnik, R. B.: "Measuring the Equation Systems of Dynamic Economics," in Statistical Inference in Dynamic Economic Models, Cowles Commission Monograph No. 10, T. C. Koopmans, editor; New York: John Wiley and Sons, 1950, Chapter II, pp. 53-237. The Linearized Maximum Likelihood version was developed by Rothenberg, T. and Leenders, C. T.: op.cit., 1964.

[18] All of the estimation methods employed were programmed for use on the Michigan State University CDC 3600 computer system by William Ruble (Assistant Professor, Department of Agricultural Economics). These routines are part of the MSU-STAT System, and they are written with double precision arithmetic (1 word = 48 bits). Additional estimation procedures are presently being programmed by Mr. Ruble, and a complete documentation of all the procedures are presented in Agricultural Experiment Station Publications (in cooperation with the MSU Computer Laboratory).

The Simultaneous Equations System Approach

With the advent and development of electronic computers the prospects for more elaborate quantitative economic research have become computationally feasible. Together with economic theory, statistical data and modern methods of statistical inference we have the tools for estimating the parameters in equations of economic behavior. Perhaps one of the brightest prospects for the use of these econometric tools lies in the area of equation systems where the primary objective is to recognize and discover the interdependent nature of economic theory and the working of the real world. The main feature of the simultaneous equations system approach to the study of economic processes is to account for the joint or mutual determination of changes in economic variables.

The simultaneous equations system approach of econometric investigation involves three important steps: (1) specification of the model, i.e., a system of relationships believed to be responsible for generating the observed data; (2) establishment of the identification of individual equations in the system; and (3) estimation of the parameters of all equations or of a subset of the equations in the system simultaneously.

Specification of the model relies heavily on *a priori* information about the commodity and markets involved together with theoretical knowledge of the econometric relationships and other relationships relevant to the study. Also it is important to consider how well the observable data represent the theoretical variables both conceptually and with regard to numerical accuracy of the data.

Identification is essentially a matter of formal logic and mathematics. Definite procedures are available for determining whether a particular equation in a system of equations is identifiable. Three classes of identification for linear structural equations have been enumerated: (1) under or not identified, (2) just identified, and (3) over identified.[19] Sometimes the latter two classes are grouped and called "identified" equations.

Statistical estimates of the parameters in structural equations of simultaneous equations models are derivable in alternative ways for identified equations. Many of the known methods of estimation were referred to above in the section on methodology, but many other developments were not discussed.

Only in the recent past have simultaneous equations estimation methods come into somewhat general use in economic research. Despite the many desired asymptotic properties of these more comprehensive analytic procedures a major problem remains: the bridge

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[19] See, for example: Koopmans, T. C.: "Identification Problems in Economic Model Construction," in Studies in Econometric Method, Cowles Commission Monograph No. 14, W. C. Hood and T. C. Koopmans, editors, New York: John Wiley and Sons, 1953, Chapter II.

between the theoretical asymptotic properties and (the more realistic) small sample properties of these estimators has not yet been satisfactorily built. Many efforts are being made toward this end, but until more knowledge is acquired in the profession and generally, simultaneous equations estimation has this most pressing limitation.[20]

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[20] Because the small sample benefits from applying the more comprehensive simultaneous equations methods are yet to be ascertained, the generally higher estimation cost is another factor that has restricted the widespread use of these methods.

CHAPTER II

THE CATTLE-BEEF SECTOR

The purpose of this chapter is to describe major aspects of the cattle-beef sector in the United States as it has evolved in the recent past and as it exists currently. The United States agricultural economy has in general been undergoing rapid development and transition in this century with marked shifts in agricultural resource-use patterns. Remarkable developments have occurred in the cattle-beef sector of the economy, but many of the changes in this sector could not have feasibly occurred without concurrent developments and achievements associated with the growth of the general economy and of other segments in the agricultural economy. Consequently, it is to be understood that the cattle-beef sector is but a component of a much larger economic system.

An Overview of the Cattle-Beef Sector

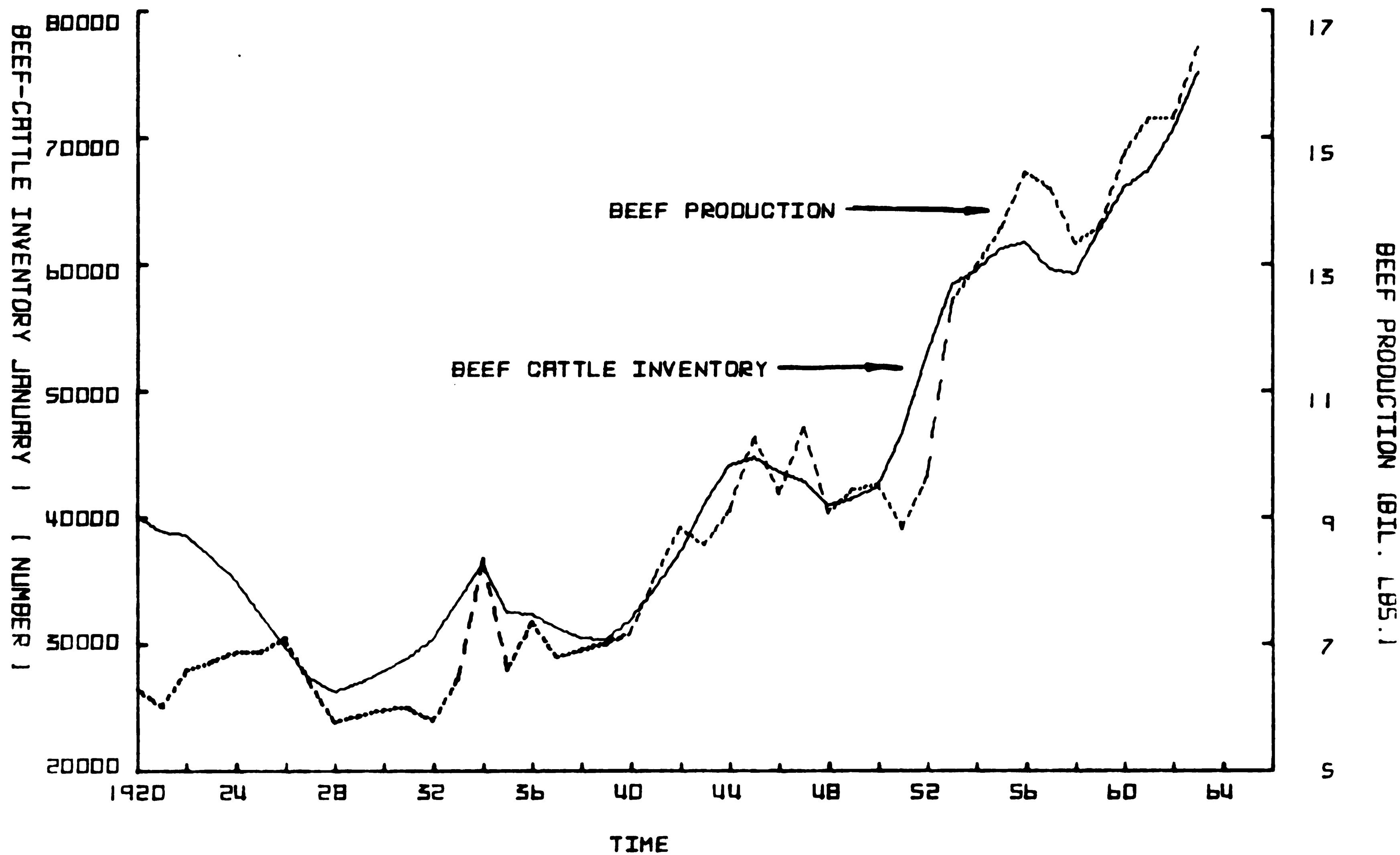
The cattle-beef sector can be viewed as three interconnected processes: production, marketing (in a broad sense), and consumption. On a year-to-year basis we can observe a flow of beef cattle for slaughter arising from the production process. Through an interaction of the production and marketing processes, farm prices for beef cattle are established and, simultaneously, the liveweight level of beef production for slaughter is determined. After slaughtering, processing and distribution, beef-meat products flow on to retail outlets where the marketing and consumption processes interact; with retail beef prices and the level of dressed weight consumption being established in this case. With this simplified account of the basic processes that are involved, a more realistic description of the processes and their interrelationships as they have evolved and as they exist is presented.

The Production Process

Viewed in the aggregate, total farm production of beef cattle flows either into production for slaughter or production for inventory, with the inventory component becoming then an input for future total production. This dual use of beef cattle is clearly an important aspect of the production process to be considered.

The following graph depicts the historical cyclical nature of beef cattle inventories and beef cattle slaughter as they have been observed since 1920. Typically these variables have moved together, i.e., slaughter in year t has increased with increased beginning period inventories, and the same movement has generally occurred during the downturn in the cycles. However, at the turning points of the inventory cycles the direction of the slaughtered beef variable has not always been the same. Various causual factors and economic conditions can be reviewed

FIGURE 2.1 TIME PATHS OF BEEF CATTLE INVENTORY AND SLAUGHTER BEEF PRODUCTION 1920-1964



and conjectured as having influenced this phenomenon whenever it has occurred[1] and, parenthetically, it is an objective of this study to "explain" as much of this variation as possible with a limited number of the alleged most important economic variables and relationships.

Another aspect of the beef cattle production process has been the geographical location of the major producing areas. One indication of the geographical distribution of the total beef cattle herd is the number of cattle and calves held as inventory on January 1, by leading states and by the divisions of the United States. This distribution is shown in Table 2.1 for 1964.

However, the total beef cattle inventory distribution as indicated does not accurately portray the fact that important differences in location have existed with regard to the cow (breeding) herd versus the feeding herd. Table 2.2 shows the leading states based on the number of beef cows 2 years and older, and based on the number of cattle and calves on feed for 1964.

Without tracing the actual movement of stocker and feeder cattle, the data in Table 2.2 implicitly reflect that a sizeable inter farm and inter state movement of beef feeders has been a

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[1] See for example: Lorie, J. H.: "Causes of Annual Fluctuations in the Production of Livestock and Livestock Products," University of Chicago Press, Studies in Business Administration, Vol. 17, No. 1, 1947. See, also: Maki, W. R.: "Decomposition of the Beef and Pork Cycles," Journal of Farm Economics, Vol. 44, August 1962.

Table 2.1

DISTRIBUTION OF THE TOTAL NUMBER OF BEEF CATTLE AND CALVES ON FARMS JANUARY 1, 1964, BY LEADING STATES AND BY DIVISIONS

Rank	State	Number (1000 head)	Percent of Total	Division Classification
1	Texas	9494	12.4	So. Central
2	Iowa	5818	7.4	W. No. Central
3	Nebraska	5604	7.1	W. No. Central
4	Kansas	4917	6.2	W. No. Central
5	So. Dakota	3686	4.7	W. No. Central
6	Oklahoma	3676	4.7	So. Central
7	Missouri	3432	4.3	W. No. Central
8	California	3320	4.2	West
9	Illinois	3072	3.9	E. No. Central
10	Montana	2516	3.2	West
11	Colorado	2425	3.1	West
12	Minnesota	2300	2.9	W. No. Central
13	No. Dakota	1831	2.3	W. No. Central
14	Kentucky	1731	2.2	So. Central
15	Mississippi	1628	2.1	
	Leading 15 States	55,450	70.3	

Rank	Division	Number	Percent of Total
1	W. No. Central	27,588	35.0
2	S. Central	22,065	27.9
3	West	16,389	20.8
4	E. No. Central	7,174	9.1
5	S. Atlantic	4,989	6.3
6	No. Atlantic	697	.9
	United States (48 states)	78,902	100.0

Source: Consumer and Marketing Service: Livestock and Meat Statistics, Supplement for 1964 to Stat. Bull. No. 333, USDA, September 1965, p. 7.

Table 2.2

DISTRIBUTION OF THE NUMBER OF BEEF COWS
2 YEARS AND OLDER, AND THE NUMBER OF CATTLE
AND CALVES ON FEED JANUARY 1, 1964, BY LEADING STATES

Rank	State	Beef Cows, 2 Years & Older (1000 head)	State	Cattle and Calves on Feed (1000 head)
1	Texas	5170	Iowa	1731
2	Oklahoma	1839	Nebraska	1022
3	Nebraska	1812	California	946
4	Kansas	1549	Illinois	716
5	So. Dakota	1521	Colorado	508
6	Missouri	1396	Minnesota	487
7	Montana	1287	Texas	478
8	Iowa	1155	Kansas	388
9	Louisiana	936	So. Dakota	329
10	California	927	Arizona	324
11	Mississippi	923	Missouri	260
12	Colorado	887	Indiana	250
13	No. Dakota	834	Ohio	210
14	Florida	813	No. Dakota	166
15	Kentucky	788	Michigan	162
	Leading 15 States	21,837	Leading 15 States	7,977
	United States (48 states)	31,729	Total States Reporting (39 states)	9,391

Source: Consumer and Marketing Service: Livestock and Meat Statistics, Supplement for 1964 to Stat. Bull. No. 333, USDA, September 1965, pp. 7 and 14.

characteristic of the production process in the recent past. To a large extent beef cattle feeding operations and beef cow-calf enterprises have, in fact, become essentially separate (but economically related) operations.

Beginning in the 1930's and particularly in the postwar period, fed beef production has increased steadily in the United States. The number of cattle and calves on feed on January 1 in the 26 major producing states averaged about 3 million head in the 1935-39 period (or about 9.4 percent of the total cattle and calves inventory). In contrast, in the 1960-64 period an average of about 8 million head were on feed on January 1 (representing about 11.4 percent of the total).[2] The absolute changes are more striking than the relative measures, but neither of these measures adequately reflect the impact of cattle feeding enterprises which have been expanded throughout the period.

Commercial cattle feedlots where large numbers of cattle are fed, usually on a year-around basis, have been expanded greatly during this period, especially in some areas. Namely, the growth of cattle feeding operations has been substantial in some Western states (California, Arizona and Colorado), in some

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[2] Based on data from: Consumer and Marketing Service: Livestock and Meat Statistics, Supplement for 1964 to Stat. Bull. No. 333, Washington: USDA, September, 1965, Table 23; and Agricultural Marketing Service: Livestock and Meat Statistics, Stat. Bull. No. 230, USDA, July 1958, Table 23.

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Northern Plains states (Nebraska and the Dakotas), and more recently in the Northwest and the Southern Plains areas. Traditionally, the Corn Belt farming area has led in beef cattle production for slaughter and it has continued to be the dominant area of such production. Nevertheless, substantial growth in fed cattle production has occurred outside of this area.[3]

There are many ramifications of the changing locations of production and changing types of beef feeding enterprises. These ramifications extend not only within the beef cattle producer segment but perhaps to an even larger extent through the marketing segment. For example, many of the large commercial cattle producers' (especially in the West) who may feed 30,000 to 50,000 or more feeders in a single operation often have coordinated directly with packers and retail outlets in the marketing segment, and thus, bypassed established markets. Another impact deals with feeder cattle procurement practices and feeder cattle movement patterns.

In this brief description of the production process many details must of course be omitted, yet a thorough knowledge of the sectors being studied is essential when a researcher seeks to prescribe a meaningful and valid set of relationships corresponding to those sectors.

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[3]See, for example: Williams, W. F. and Stout, T. T.: Economics of the Livestock-Meat Industry, New York: The Macmillan Co., 1964, pp. 286-291.

Viewed broadly again, the main agricultural feature of the states leading in the size of the breeding or cow herd is the vast areas of grassland and ranges in these states. When the 15 leading states are classified by their division or region of the United States, there are 6 leading states in the West North Central, 5 in the South Central, 3 in the West and 1 in the South Atlantic division.

In contrast, the main agricultural feature of the states leading in the number of cattle and calves on feed is the large amount of land suitable for feed grain production and/or other concentrate-type feed production. In this case there are 7 states in the West North Central division leading in the number of cattle and calves on feed, 4 in the East North Central, 3 in the West, and 1 in the South Central division.

Typically, feeders have been shipped into the feed producing areas rather than the shipping of feed products into the principal breeding herd areas where many calves are raised. Some of the factors which have influenced this general pattern of movement are overall shipping cost considerations, the heavy concentration of meat packing and processing facilities established near the feeding areas, the nearness of large metropolitan consuming centers where the finished beef products are principally distributed, and the availability of labor for the meat packing and distribution agencies.[4]

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[4]Williams, W. F. and Stout, T. T.: op.cit., pp. 82-85.

So far no mention has been made of price relationships which are certainly relevant to the production process. To do so requires a discussion of other attributes of the production for slaughter component. First, there have been seasonal variations in total production for slaughter; and second, there have been seasonal variations in classes of slaughter. The total slaughter of cattle and calves has been reasonably well distributed throughout the year, but the composition of slaughter has varied more from month to month than did total volume.

Slaughter of all cattle and calves has been normally the greatest in October, principally due to the many cows slaughtered during that month. Cow slaughter has been the most highly seasonal class of slaughter and has given the total slaughter a seasonal swing from a Fall high to a late Winter or early Spring low. More steers have normally been slaughtered in the Spring than at other seasons; while heifer slaughter has been greatest from October to February. Calf slaughter usually has been the highest in October and November, and has been the lowest during January and February.[5]

Associated with seasonal variations in slaughter (especially by classes of slaughter) were seasonal variations in prices received by farmers for the various classes of livestock. It is

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[5] Breimyer, H. F. and Kause, C. A.: Charting the Seasonal Market for Meat, Washington: USDA, Ag. Handbook No. 83, June 1955.

through variations in livestock prices that producers of beef cattle have been most affected economically and their decisions regarding future production adjusted.

The trend toward higher levels of feed beef production on a year-around basis has reduced seasonal variations in total slaughter; yet the practice of marketing many cattle at the end of the Summer grazing period has continued to cause a Fall high in total slaughter.

Conceptually, any production process requires inputs in order to produce an output; and in beef cattle production, feed, labor, land, and capital and equipment are the most important resources used. Consequently, one can readily perceive that economic conditions prevailing in the feed economy, the labor markets, and the capital goods and equipment markets assuredly have an important bearing on the cattle-beef sector. In this study, conditions outside the cattle-beef sector proper are generally taken as given, i.e., predetermined; except for relationships in what will be referred to as the other livestock-meat sector.

In the aggregate, other livestock[6] producers often compete

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[6]Other livestock refers to hogs, sheep and lambs, chickens, turkeys, and dairy calves (for veal) in this study. Chickens and turkeys are not normally referred to as livestock. Dairy calves (as a "by-product" of the dairy industry) are the dominant source for veal meat products; hence, veal production and consumption are aggregated with the other livestock-meat sector variables, rather than the cattle-beef sector variables.

directly with beef cattle producers for such resources as feed and in many cases for labor and capital resources. Thus, another dimension is added to the study of the production process of the cattle-beef sector. While this interrelationship of beef cattle and other livestock enterprises is believed to have been important, it is believed that to an even larger extent, there are important indirect factors affecting the beef cattle and other livestock production processes.

Beef and other meat products are considered in the aggregate to be relatively close substitutes in consumption.[7] Movement along one demand function (e.g., other meat) results in a shift in the demand for the other (e.g., beef). But since the farm demand for these two different groups of livestock are considered to be derived demand functions, there is a corresponding shift in the demand function (e.g., beef cattle) at the farm level. Consequently, it seems apparent that an analysis of the cattle-beef sector must simultaneously involve an analysis of the other livestock-meat sector. This study treats the other livestock-meat sector more directly than other sectors of the general economy, by incorporating demand and supply relation-

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[7]By relatively close substitutes in consumption, we mean that cross-price elasticities of beef and other meats are relatively large (but far from 1) as compared to similar elasticities for beef and non-meat foods. See, for example: Brandow, G.E.: "Interrelations among Demands for Farm Products and Implications for Control of Market Supply," Pennsylvania Ag. Expt. Sta. Bulletin 680, August 1961, p. 17, for a comparison of cross-price elasticities for various food groups.

ships of this sector in the model that will be developed.

The Marketing Process

In a broad sense the marketing process can be viewed as a provision of services by firms in the marketing segment that facilitate the movement of cattle-beef products from producers to ultimate consumers. A wide range of institutional arrangements exist to carry out the basic functions of the marketing process in order to provide the ultimate consumer with beef products in the form, place, and at the time desired. A vital feed-back function is implicit in the marketing process, in that marketing firms and institutions are the principal mode for reflecting consumer demands to the producers of beef cattle.

The marketing process, i.e., the processing and distribution of livestock and meat, is normally classified into four broad functional categories: (1) marketing livestock, including transportation, (2) meat packing, (3) meat wholesaling, and (4) meat retailing. The degree to which these functions may be vertically coordinated is a subject that is being continually studied, but for the purpose of this study, a brief description of each of the four functional categories should suffice to indicate that the marketing process involves a complex pattern of interrelationships.

Marketing Livestock

In most areas where beef cattle are produced, producers usually have several alternative outlets (channels) available for marketing their animals. These outlets include terminal public markets, auction markets, and various forms of "country selling". Country selling includes sales by producers direct to packers, to livestock dealers, and to other farmers.[8]

Changes in the structure and in the pattern of livestock marketing during the past forty years have resulted in a decline nationally in the relative importance of terminals as a market outlet. This decline has been characterized as a trend toward a decentralized marketing structure. Increased volume of marketing through country selling methods occurred initially in the 1920's and early 1930's, and this method of selling has been expanded. The most dramatic change in livestock marketing which contributed to the relative decline of the central markets, however, was the rapid growth in the number of livestock auction markets since 1930. In 1930, only about 200 auctions were in operation, but by 1937 the number had increased to 1,345. The number of auctions continued to rise rapidly until a peak of about 2,500 was reached in 1952. A decline to 2,322 auctions occurred by 1955, but since then the number has risen slightly.[9]

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[8]A general reference of the livestock-meat economy on which much of the following discussion was based is the following: Williams, W. F. and Stout, T. T.: op.cit., 1964, pp. 802. This book contains an extensive bibliography.

[9]Engelman, G. and Pence, B. S.: "Livestock Auction Markets in the United States," Washington: USDA, Mktg. Res. Rpt. No. 223, 1958, pp. 37.

The early growth of auction markets was concentrated in the North Central region, but the development soon spread into the South, Northeast and West. By 1955, livestock auction markets were located throughout the United States.

Several factors provided stimulus for the development of the decentralized livestock marketing system. Extension and improvement of the highway network and increased reliance on trucks for transporting livestock have provided considerable flexibility to producers when choosing their marketing outlets. Expansion of the Federal Livestock Market News Service and improved market news dissemination have greatly facilitated the "non-terminal" outlets in attracting producers' sales. (Current market news about changes in prices at major terminals and other major marketing centers has in general been a basis for adjusting offerings for livestock at "non-terminal" outlets. Consequently, non-terminal marketing outlets have generally been looked upon by producers as representative of the broader regional and national marketing system demand and supply conditions.)

Another factor contributing to decentralization of livestock marketing has been the relocation (and decentralization of firms in the meat packing industry. Whether or not the decentralization of the meat packing industry was a cause or a result of the decentralization of livestock marketing is debatable, but perhaps more accurately, the decentralization of both was concurrent. These newer meat packing facilities were generally located in areas near major sources of slaughter animals, which are also the areas where the most recent livestock markets have been established.

There have been differences by geographical regions in the principal market outlets used by producers; and further, there have been differences with regard to species of livestock. For cattle (including dairy), the percentage breakdown by regions and by type of market outlet in 1955 were as follows:

Table 2.3

PERCENTAGE DISTRIBUTED OF ALL CATTLE SOLD BY FARMERS THROUGH DIFFERENT MARKET OUTLETS, BY GEOGRAPHICAL REGIONS, 1955

	Percentage Sold Through Market Outlets						
			Country Sales				
Region	Terminal Public Markets	Auctions	Direct to Packers	Local Dealers	Farmers	Total Cattle Sales	All Other
Northeast	21	36	3	22	15	40	3
North Central	54	22	11	6	6	23	1
South Atlantic	4	68	8	13	6	27	1
South Central	16	46	6	11	19	36	2
Mountain	39	22	11	10	10	31	8
Pacific	17	8	39	16	17	72	3

Source: Phillips, Victor B., and Engleman, Gerald: Market Outlets for Livestock Products, Mkg. Res. Rpt. No. 216, Agric. Mkg. Ser., USDA, March 1958, p. 23.

In summary, terminal markets were the major outlets for cattle sales in the North Central and Mountain regions. In the South Atlantic and South Central regions, auctions were the principal market outlets. In the Northeast, both auctions and country sales were dominant methods of marketing; and country sales led substantially in the Pacific region. (A limitation of this data should be mentioned: percentage distributions of sales by producers do not account for interfirm or interagency sales or shipments of livestock; and consequently, do not completely portray the relative importance of the various marketing channels. Nevertheless, it is clear that no single type of market outlet is completely representative as the major producer marketing channel in all regions of the United States).

Meat packing

"Meat packing", as a functional category, refers to a combination of slaughtering and processing operations. The term originated prior to the development of modern refrigeration when most livestock were slaughtered during the winter and the product was "packed" in salt or brine for consumption during the warmer seasons. Even though modern slaughtering and processing operations are markedly different from the past, the term "meat packing" is still generally used.

Slaughtering operations have been classified in numerous ways.[10] One indication of the scope of the slaughtering plant operations is the number of livestock slaughtering plants by type of slaughter and the relative importance of each type of slaughter. In 1960, there were 3,144 commercial slaughtering plants in the United States. Of these, 530 (16.9%) were

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[10] See, for example: Williams, W.F. and Stout, T.T.: op.cit., p. 62.

Federally Inspected plants, which accounted for 77.4 percent of all cattle slaughter. Another 902 (28.7%) plants were classified as wholesale, and 1,712 (54.4%) were local plants.[11,12] Combined, the wholesale and local slaughtering plants accounted for 20.0 percent of the cattle slaughter. The remaining 2.6 percent of cattle slaughter was farm slaughter.

The general acceptance and expansion of the Federal Meat Grading System for carcass beef, especially in the post World War II period, has been a major factor contributing to the high proportion of beef cattle that are slaughtered under federal inspection. Not only have consumer preferences thereby been reflected more accurately back through the marketing system to producers, but also the marketing process has been enhanced because graded beef meat products can be purchased by retail outlets on a specification basis (i.e., buying and selling by description rather than through personal inspection). Another consequence largely attributable to the Federal Meat Grading System has been the decline in the concentration within the meat packing industry, with less dependence being placed on private labels for quality assurance.

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[11] Ibid., p. 63; and also in Agricultural Marketing Service: "Number of Livestock Slaughter Establishments, March 1, 1960," Washington: USDA, August 1960.

[12] Wholesale plants are those slaughtering 2 million pounds of liveweight or more annually; and local plants are those slaughtering less than 2 million pounds liveweight annually but more than 300,000 pounds.

The changing structure of the meat packing industry can be observed in part by noting the changing geographical percentage distributions of commercial cattle slaughter (liveweight) by regions over time.

Table 2.4

PERCENTAGE DISTRIBUTION OF COMMERCIAL CATTLE SLAUGHTER (LIVEWEIGHT) BY REGIONS, 1947 AND 1962, UNITED STATES

Region	Cattle 1947	Cattle 1962	Per Cent Change
North Atlantic	10.5	8.6	-1.9
North Central	57.4	55.2	-2.2
E.N. Central	25.0	18.3	-6.7
W.N. Central	32.4	36.9	4.5
South	16.4	15.6	- .8
S. Atlantic	4.7	4.6	- .1
E.S. Central	3.2	3.8	.6
W.S. Central	8.7	7.2	-1.5
West	15.7	20.6	4.9
Mountain	4.4	7.8	3.4
Pacific	11.3	12.8	1.5
United States	100.0	100.0	

Source: Statistical Reporting Service: Livestock Slaughter, Number and Liveweight By States, By Months, USDA Annual Series.

The major areas with gains in the relative level of commercial cattle slaughter from 1947 to 1962 were the West North Central, Mountain, and Pacific regions. Those regions with the largest relative losses were the East North Central, North Atlantic, and West South Central. These interregional shifts in location of slaughter volume are an indication of the decentralization of the meat packing industry that has occurred concurrently with shifts in livestock marketing patterns (discussed above).

Meat Wholesaling

The meat wholesaling function is principally the sale and distribution of meat products from the meat packing plants to retail outlets. Again, a wide range of institutional arrangements and marketing channels has been utilized in providing this service.

The major channels which have been used in the past include (1) direct sales by packers to retailing outlets and to H.R.I. (hotels, restaurants, and institutions), (2) distribution through packer branch houses, and (3) distribution by independent wholesalers and jobbers. Some important structural changes also have occurred in the wholesale distribution system for meat and meat products. The more significant changes have been a decline in the relative importance of packer branch houses as wholesale meat distributors, and an increased share of meat products moving through independent wholesalers. Also, direct sales by packers to retailing outlets and to H.R.I. have generally increased during the past 30 years.

For all meat and meat products the following data on estimated distribution of sales by meatpackers to different classes of customers gives some indication of the changing structure in the meat wholesaling industry over time.

Table 2.5

ESTIMATED DISTRIBUTION OF SALES BY MEATPACKERS
TO DIFFERENT CLASSES OF CUSTOMERS, FOR SELECTED YEARS

Year	Packer Owned Branch Houses	Independent wholesalers and jobbers	Retail Stores	Institutions and Other Large Users	Export	Total
			(percent)			
1929	47	14	32	4	3	100
1935	34	11	46	8	1	100
1939	30	11	49	8	2	100
1948	20	11	59	9	1	100
1954	19	16	55	9	1	100

Source: Agricultural Marketing Service: Marketing Costs and Margins for Livestock and Meats, Mktg. Res. Rpt. No. 418, USDA, 1960.

When some of the factors which contributed to the changing structure of the meat wholesaling industry are reviewed, the explanations cited are generally much the same as those cited as factors contributing to the changing structure in other segments of the livestock-meat sector. Namely, (1) the improvement and extension of the highway system and trucking equipment (with modern refrigeration units) have facilitated the movement of meat direct from packers to retailers, and (2) the development of the U. S. meat grade standards facilitated the sale and distribution of meat on a specification basis.

Procurement practices of the large-scale retailing organizations, who require high volume, fresh, uniform quality meat, have been such that direct purchases have been economically feasible. Also, the demand for the types of specialized services offered by many of the independent wholesalers has increased substantially and their role in meat distribution has increased in importance in the recent past. Another recent facet of the meat wholesaling industry has been vertical alignment with retail food chains that involve centralized processing (e.g., breaking and packaging) before deliveries are made to the individual stores.

Meat retailing

The final functional category of the marketing process to be briefly discussed is that of meat retailing.[13] Major outlets for meat products to consumers have been retail grocery stores; hotels, restaurants, and institutions; meat markets; and other food stores. Since the early 1940's grocery stores and the H.R.I. trade have accounted for increasing shares of retail sales.

Meat marketing practices in retail grocery stores have changed substantially since the 1930's with meat sales accounting for about 25 percent of the total dollar sales in most modern retail supermarkets. The increased importance of meat retailing by supermarkets is a major aspect of structural changes that have occurred in the food retailing industry since the first appearance of supermarkets in the 1930's. Prior to this time a

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[13] A general reference on the following discussion is again: Williams, W. F. and Stout, T. T.: op.cit., especially Chapter 16, "Structural Changes at Retail," pp. 402-426.

very small proportion of fresh meat was distributed through grocery stores, with considerably more being sold through specialized meat markets.

A supermarket "era" emerged as the nation's larger retail food chains became established and increasingly accepted by the public. The total number of grocery stores increased during the 1930's with the largest increases occurring among stores handling fresh meat. World War II inhibited many adjustments and changes but the pressure for larger retailing units continued to mount. At the War's end, with the sharp population increase and the exodus to the suburbs apparent, shopping centers with supermarkets increased. By 1948, grocery stores with fresh meat had increased and the average size of these stores had risen sharply.

Another major development that occurred in meat retailing in recent years was a trend toward self-service operations. Again, the larger chains apparently led this development with increased emphasis placed on quality, uniformity and variety. Economic pressures continued on smaller grocery store units; and the number of grocery stores dropped 28 percent to about 260,000 in 1958, from about 360,000 in 1948. Even more dramatically, the average volume of sales per store, in constant dollars, more than doubled between 1948 and 1958, from about $80,000 per grocery store to approximately $170,000.[14] By 1958,

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[14] Ibid.; p. 406; and also, Bureau of Census: "Retail Trade," U. S. Census of Business, Washington: U.S. Dept. of Commerce, census issues for 1948, 1958.

nearly all of the larger grocery stores handled fresh meats.

The original concept of supermarket food merchandising referred mainly to a way of doing business, rather than so much emphasis on size. Originally, supermarkets were characteristically thought of as discount houses for food products. However, in the postwar period, with increased competition among the larger retail chains and supermarkets, there were pressures for retail stores to increase both the number of items distributed and the services offered. In the recent past, added services have been offset partially for meat by self-service merchandising and economies in procurement, cutting and handling. Many of the in-store meat cutting, trimming and wrapping operations have become highly mechanized and routinized. On the other hand, there has been some shift of the processing services back to packers and other distributors; and increased centralized processing among chain-stores. These factors may lead to important developments in the structure of the meat wholesaling industry.

Many other developments in the retail food industry have had and are having an impact on the structure of the industry. Other segments of the retail trade for meat include H.R.I., delicatessens, the food locker industry, and various types of home freezer plans. H.R.I. has been by far the most important segment of this group in recent years. About 18 percent of the food sold to U. S. civilians is handled by eating establishments, including public and private institutions. Meat products are an important part of these sales, but no data are available on this consumption by commodity groups. It is known, however, that a high percentage of dining establishments purchase meat through jobbers or specialized hotel supply houses. Also, some of the larger firms buy direct from the packers.[15]

The complexity of the overall marketing process for meat products poses some particularly difficult questions in studies of this kind where a main objective is to simplify and tie together into a limited number of economically meaningful variables and relationships the underlying dynamic processes of meat production, marketing and consumption. But, before "building-the-bridges" in the form of an economic and statistical model, we should consider the last of these processes; namely, the consumption process.

The Consumption Process

Meat and meat products account for about 25 percent of family food expenditures. Beef meat products have accounted for the largest single-species share (both by weight and by value) of the meat consumption in the United States since 1947, and the per capita consumption of beef has increased relative to the other red meats in the postwar period. In the decade from 1952 to 1962 the per capita consumption of beef rose 44

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[15] Williams, W. F. and Stout, T. T.: p. 420.

percent, from 62 to 89 pounds.[16] Further increases to 100 pounds per capita were reached in 1964, a new record level of beef consumption per capita.[17]

The phenomenal increases in beef consumption per capita are the result of many factors. Part of the increase was associated with a shift to beef consumption relative to other meats, and also, associated with shifts from other food groups to higher levels of total meat consumption, particularly beef and poultry meats in recent years. Some of the major trends in food consumption patterns are evident in the following table (Table 2.6) where the per capita consumption of food by major groups in selected periods are presented.

In summary there have been increasing trends in per capita consumption of beef and poultry meats. Fish, dairy products, fats and oils, vegetables, potatoes and sweet potatoes, and sugars and sweetners have been food groups that remained essentially stable in recent years. Finally, other meats (including pork, veal, lamb and mutton), fruits, and flour and cereal products consumption per capita have been generally declining over the periods shown.

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[16] Based on data from: Economic Research Service: "U. S. Food Consumption, Sources of Data Trends, 1909-63," Washington: USDA, Stat. Bull. No. 364, June 1965, p. 22.

[17] Preliminary estimate as cited in: Consumer and Marketing Service: "Livestock and Meat Statistics," Washington: USDA, Supplement for 1964 to Stat. Bull. No. 333, September 1965,p. 146.

Table 2.6

PER CAPITA CONSUMPTION OF FOOD
BY MAJOR GROUPS IN SELECTED PERIODS

	Meat	Poultry	Fish		Dairy Products	Fats & Oils	Fruits	Vegetables	Potatoes & Sweet Potatoes	Flour & Cereal Products	Sugar & Other Sweetners
	Beef[a] lb.	Other Meat[b] Excluding Poultry lb.	Poultry[c] lb.	Fish[d] lb.	Milk Equivalent (Excluding butter) qt.	Total including Butter lb.	Total including mellons lb.	Total Excluding Potatoes & Sweet Pot. lb.	Total lb.	Total lb.	Total lb.
1909-13	68.2	80.4	17.5	13.3	177	40.6	176.3	203.0	205.0	291	89.1
1925-29	54.5	80.6	16.6	13.7	191	47.8	188.5	216.9	162.0	237	118.6
1935-39	55.6	71.4	16.2	13.1	202	49.3	199.0	231.1	137.0	204	110.5
1947-49	65.5	82.9	22.4	12.8	236	45.5	207.7	231.6	122.7	171	109.5
1957-59	82.2	74.4	33.9	13.3	240	48.6	182.6	208.8	109.8	148	108.5
1960	85.0	75.8	34.7	13.2	238	48.5	184.0	210.0	109.5	147	108.8
1961	87.8	72.7	38.0	13.7	235	48.4	177.9	208.3	110.0	146	109.1
1962	88.8	74.3	37.4	13.6	235	48.8	174.2	207.4	108.8	144	109.8
1963	94.2	75.1	38.0	13.6	235	49.9	161.5	208.2	114.4	144	110.0

a) carcass weight; b) carcass weight; includes pork, veal, and lamb and mutton. Does not include edible offals or game; c) ready-to-cook basis; d) edible-weight basis. Includes game fish.

Source: Economic Research Service: "U.S. Food Consumption, Sources of Data and Trends, 1909-63," Stat. Bull. No. 364, USDA, 1965, pp. 22, 68 and Agricultural Marketing Service, "Meat Consumption Trends & Patterns," Ag. Handbook, No. 187, USDA, 1960, pp. 34.

A wide variety of economic and sociological factors are generally believed to have accounted for these shifts in per capita consumption, particularly for beef. Among these are production characteristics, the level of consumer disposable income, prices of beef relative to other meat and meat products, beef (and other meat) prices relative to prices of other food, changes in tastes and eating habits, effects of urbanization, size and age distribution of the family, occupations, race, religion and nationality.[18]

Since most beef consumed in the United States has been fresh meat and not well suited for storage for long periods of time, "current" consumption has been closely tied to "current" slaughter at the farm level. In the short run, slaughter production largely determines consumption. On the other hand, in the longer run situation, consumer demand largely determines the level of farm production at specified prices, and in this sense changes in consumer demand have influenced production trends.

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[18] Most of these factors are briefly discussed by: Williams, W. F. and Stout, T. T.: _op.cit._, Chapter 4, "Meat Consumption," pp. 86-105. Also see, for example: Stout, R.G., Purcell, J. C. and Fishel, W. L.: "Marketing, Slaughter and Consumption of Livestock and Meats in the South," Southern Cooperative Series, Southern Regional Expt. Stations Bull. No. 66, August 1961; Agricultural Marketing Service: _Meat Consumption Trends and Patterns_, Washington: USDA, Ag. Handbook No. 187, July 1960; and Lanahan, Thomas J., Jr.: "A Review of 1955 Survey Data on Household Meat Consumption," _The National Food Situation_, April 1957.

The increased level of consumer disposable income apparently has been one of the main factors responsible for the shifts to higher levels of meat consumption. Our marketing and consumption processes effectively merge only when the consumers' preferences are backed by their ability to pay for the goods desired. The higher costs of meat production relative to production costs of other foodstuffs with equivalent nutritive-values has meant that consumers both prefer and are able to purchase meat products.

Beef and other meats are relatively close substitutes in consumption and the relative prices of the various meats have influenced consumers' choices and demand for alternative meat products. Likewise, meats and other foods are substitutes to some extent, but generally not to the same degree as the various meats.

Meat consumption patterns have been further influenced by the availability of many processed forms of meat (e.g., luncheon and variety meats, wieners, meat pies, and others). Processed meat consumption has increased steadily since the late 1930's, and price interrelationships among alternative forms of meat have been affected. (Most processed meats are pork products, however; whereas beef has been marketed primarily as fresh meat). Increased consumption away from home in various kinds of dining establishments, both private and institutional, has also affected meat consumption patterns and interrelationships.

The other factors mentioned have been cited as phenomena influencing meat consumption patterns, and some factors have been important in particular areas of the nation. For example, teenagers consume more meat than the average adult; consequently, the changing composition of population should be a consideration in studies aimed at explaining demand for meat. Another example of a factor which should at least be considered is the effect of the kosher trade, especially in the Northeast, on the overall consumption levels of meat. These factors and possibly many others complicate efforts to simplify and quantify aggregate demand relationships.

Summary

In summary, three interrelated processes of beef production, marketing and consumption have been briefly reviewed. Each process, by itself, was seen to be a source of many complex patterns of involvement, and each process is linked to the others.

Beef production was viewed as the raising of beef cattle for one of two uses; either production for slaughter or production for inventory. The inventory component then was considered as an input for future total beef production. Geographically, the beef breeding herd was seen to be principally located in the grassland and range areas of the country; while the feeding herd was seen to be located primarily in those areas where feedstuffs, such as feed grains, are grown. These differences were considered relevant to the overall production process.

Variations in seasonal slaughter of beef cattle were considered as important to producers of various classes of livestock (but this study is based on annual time series data, so the full affects of seasonal variations will not be accounted for in this analysis). However, the trend toward larger feeding herds, especially on a year around basis, has tended to reduce seasonal variations in slaughter.

Producer sales out of first hands normally have flowed into alternative marketing outlets, with terminals, auctions and country selling methods each being important marketing channels. The relative importance of each was seen to vary across regions of the United States.

The marketing of livestock was discussed as the first functional category of the marketing process. Three other broad categories of the marketing process discussed were meat packing, meat wholesaling and meat retailing. Meat packing referred to a combination of slaughtering and processing operations, which was but an intermediate step in the marketing process. The meat packing industry was seen to be well distributed throughout the United States and a changing structure of the industry was characterized as a trend toward decentralization. Packing plants have been substantially relocated over time and new locations have generally been closer to major producing areas of beef cattle and other livestock.

Meat wholesaling refers to the sale and distribution of meat products from packers to retail outlets. Direct sales to retail stores and institutions, independent wholesalers and jobbers, and packer owned branch houses are the main channels. As the nation's highway system developed, as trucks with modern refrigeration units came into use, as the Federal Meat Grading System expanded (thereby allowing the smaller packers to merchandise meat without a well known brand name), and as the meat packing industry became decentralized, the meat wholesaling industry has likewise been decentralized. The major relative decline occurred in sales moving through packer owned branch houses, with both the independent wholesaler and the direct sales channels gaining relatively.

Meat retailing has changed markedly since the 1930's with the growth and development of supermarkets. Retail grocery stores have become the principal outlets for meat wholesalers, with hotels, restaurants and institutions becoming somewhat more important over time. Larger retail grocery stores, namely chains and supermarkets, have dominated however, and their procurement practices have had reverberations throughout the meat economy. Implementation of self-service merchandising in the postwar period has been a major development in meat retailing and its widespread adoption, combined with the large scale retail outlets, has resulted in considerable structural change in the food retailing industry; mainly in the reduction of the total number of stores and large increases in the average sales volume of the remaining stores.

The meat retailing industry has direct access to consumers and here the marketing and consumption processes interact. Consumption of meat (beef in particular) has increased sharply in the postwar period. In fact, meat products (including poultry) as a food group is the only group with rising consumption per capita from the 1930's to the present time.

Many factors are believed responsible for this rise in consumption of meat, especially beef. In the short run, meat consumption is closely tied to slaughter production; but in a longer run situation, the level of consumer demand affects the level of production. The level of consumer disposable income seems to have been a major determinant of increased demand for beef. Also, relative prices of beef and other meats, and of beef and other foods have had additional influences on the level of beef consumption. Changes in tastes and eating habits, composition of the population, and several other factors were briefly mentioned as sources of influence on the changing demand for beef by consumers.

With this brief background on the cattle-beef economy, and its relation to other sectors of the economy, there are some guides, or perhaps more accurately, some constraints, within which an economic model of the cattle-beef sector may be developed. An objective of this study is to consider a system of relationships which integrates some of the interrelationships between the consumer, marketing and producer segments. Clearly, these segments are interrelated.

Literature Review

Numerous studies have dealt with various aspects of the cattle-beef sector or interrelationships of the cattle-beef sector with other sectors of the general economy. These studies have differed in the approach taken, in the time period analyzed, in the level of aggregation, in the estimation methods employed, and in the types of interrelationships considered. The purpose of this section is to report on only a limited number of previous studies which had a bearing on development of this study. Later in this report some findings of these and other studies will be compared with results of this analysis.

A pioneering effort employing national aggregate variables of the livestock and feed grain economies in a simultaneous equations framework was reported by Hildreth and Jarrett[19] in 1955. Their effort focused attention on the economic interdependence of the average price of livestock produced, quantities of livestock produced and sold, and prices of feed grains and

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[19] Hildreth, C. and Jarrett, F. G.: A Statistical Study of Livestock Production and Marketing, Cowles Commission Monograph No. 15, New York: John Wiley and Sons, 1955.

protein feeds. A similar more recent study was developed by Feltner[20] (1964) to account specifically for changes in aggregate livestock inventories.

Two other early studies which were formulated within a structural model simultaneous equations framework at a lower level of aggregation were those by Nordin, Judge and Wahby[21] (1954), and by Judge[22] (1954). In the former study, the authors considered interrelationships of retail demand and supply functions of pork, beef, poultry products, dairy products, oleomargarine and feed grains; plus a production function for feed grains. Their main focus for estimation was on derived demand relations for pork, beef, and poultry products. Judge's study considered aggregate demand and supply interrelationships for eggs, meat, and other foods at the retail, commercial and farm levels. Both of these studies emphasized development of econometric models.

Working[23] (1954) discussed interrelationships among demand functions for various meats, although a simultaneous equations

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[20]Feltner, R. L.: Alternative Models of the Feed-Livestock Economy, North Carolina State University, Raleigh, Ph.D. thesis, 1964.

[21]Nordin, J. A., Judge, G. G., and Wahby, O.: "Application of Econometric Procedures to the Demands for Agricultural Products," Iowa State College, Ames, Ag. Expt. Sta. Res. Bull. No. 410, July 1954.

[22]Judge, G. G.: "Econometric Analysis of the Demand and Supply for Eggs," University of Connecticut, Storrs, Ag. Expt. Sta. Bull. No. 307, 1954.

[23]Working, E. J.: Demand for Meat, Chicago: University of Chicago Press, 1954.

application was considered only in an appendix discussion. Fox[24] (1953) presented a few simple simultaneous equations systems, but his emphasis was on appraising the applicability of single equations methods for fitting demand functions for agricultural commodities. The dates of the above references were noted to emphasize that these studies (except Feltner's) were developed prior to modern developments in estimation procedures and prior to major advances with computers.

Wallace and Judge[25] (1958) presented two more comprehensive models, each involving twelve relationships of the beef and pork sectors of the economy. Demand and supply relations at both the farm and retail levels were considered, and alternative estimators (LISE, 2SLS, OLS) were applied to a selected set of equations from the systems.

Cromarty[26] (1959) introduced an econometric model that examined twelve product categories (involving demand, supply and price relationships) within the agricultural economy. His study was a continuation of a comprehensive project begun by Klein and

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[24]Fox, K. A.: "The Analysis of Demand for Farm Products," USDA, Tech. Bull. No. 1081, 1953.

[25]Wallace, T. D. and Judge, G. G.: "Econometric Analysis of the Beef and Pork Sectors of the Economy," Oklahoma State University, Stillwater, Oklahoma Ag. Expt. Sta. Tech. Bull. No. P-75, August 1958.

[26]Cromarty, W. A.: "An Econometric Model for United States Agriculture," <u>Journal of the American Statistical Association</u>, Vol. 54, Sept., 1959.

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Goldberger[27] (1955) which linked both the agricultural and non-agricultural sectors of the total United States economy within a system framework. The primary purpose of such grand or "master" models was to measure major relationships within and between the agricultural and non-agricultural sectors of the total economy. These latter two references illustrate how one might proceed to integrate less-aggregative components of a system to the more-aggregative "master"-model of an economy.

Other researchers have taken alternative approaches to account analytically for interrelationships within the cattle-beef sector and with other sectors. Recent related research includes a study by Maki[28] in 1962, where he concentrated on developing market forecasting procedures by decomposing beef and pork production cycles into several interacting components. Nine multivariable equations were specified to obtain estimates of the functional relationships for the beef-pork economy; and the method of least squares was employed in fitting annual, semi-annual and quarterly data for the 1949-1960 sample period. Variables used in the study involved a more detailed breakdown of livestock classes than had previously been attempted in similar studies.

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[27] Klein, L. R. and Goldberger, A.S.: An Econometric Model of the United States, 1929-1953, Amsterdam: North Holland, 1955.

[28] Maki, W. R.: "Decomposition of the Beef and Pork Cycles," Journal of Farm Economics, Vol. 44, August 1962, pp. 731-743.

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Maki[29] presented another econometric model of the beef and pork sectors in 1963, with the particular emphasis of demonstrating its empirical application in analyzing and forecasting cyclical fluctuations in livestock supplies and prices. An important aspect of this analysis was the use of inventory relations in a comprehensive forecasting model of the livestock economy. Prior to the development of the final system of prediction equations in the study, a series of inventory and cobweb models of the beef and pork producing sectors, and a series of vertical price relationships were specified and fitted using the least squares method. Combining the production and supply relationships at the farm level with the vertical farm and wholesale price relationships, a recursive system of 44 prediction equations was obtained to generate the principal endogenous variables of the overall model.

Crom and Maki[30] have developed a semi-annual dynamic model of the livestock-meat economy, which is adjusted so as to improve its predictive ability. Such models may be recursive, simultaneous, or both (recursive and simultaneous subsets); but in any case the development of such dynamic models has relevance

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[29] Maki, W. R.: "Forecasting Livestock Supplies and Prices with an Econometric Model," Journal of Farm Economics, Vol. 45, August 1963, pp. 612-624.

[30] Crom, R. J. and Maki, W. R.: "Adjusting Dynamic Models to Improve Their Predictive Ability," Journal of Farm Economics, Vol. 47, November 1965, pp. 963-972.

to studies like this one. A recent study by Petit,[31] which included a recursive model formulation of the beef cattle producer segment, is another example of an alternative analytical approach. We discuss Petit's methodology and some of his findings in more detail later in this report.

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[31] Petit, M. J.: Econometric Analysis of the Feed-Grain Livestock Economy, Ph.D. Thesis, Michigan State University, 1964.

CHAPTER III

THE ECONOMIC AND STATISTICAL MODELS

Definitions and Concepts

In order to discuss econometric model construction and statistical inference more efficiently and accurately, it is helpful to use language that has been developed to consider statistical analysis of economic relationships. Some basic defintions and concepts will be presented in this section.

Concepts of a model and a structure are fundamental. A model is a more general concept that refers to a set of structures. A structure is defined as the process by which a set of economic variables is generated. A structure can be thought of as a unique representation of the model, i.e., it is a member of the set of structures. This distinction is useful in that empirical analysis is aimed at determining a single structure, including estimates (via statistical estimation or by assumption) of all unknown parameters of the model.

The number and nature of the parameters of the model have to be ascertained. Two types of specifications are essential for obtaining meaningful parameter estimates: (1) economic specifications, and (2) statistical specifications. Economic specifications are generally summarized in terms of an economic model. Economic theory and knowledge of the economic institutions and characteristics pertaining to the sector(s) being studied, are important in this phase of the analysis.

In addition, the researcher is required to make statistical specifications (or assumptions, e.g., functional forms of the relationships, form of the variables, distribution of random variables, and others). About which *a priori* economic knowledge and theory may offer little if any guide. Since statistical specifications are supplementary to economic specifications, then the combined specifications are generally summarized in terms of a statistical model.

In the simultaneous equations system framework the components of an economic model can be classified into categories of variables, endogenous and predetermined. The variables whose values are explained by the structure are called endogenous variables. The predetermined variables are further classified as being either exogenous or lagged endogenous. The variables whose values are determined outside the structure are called exogenous whereas those variables whose values are determined by the structure prior to the current period are called lagged endogenous. In other words the endogenous variables are to be explained by the system of relationships while the predetermined variables are specified as being determined at the time they enter the structural relationships.

There is a third type of variable which enters in the statistical model called a disturbance or shock variable. This is a random variable that is not directly observable but its probabilistic behavior can be described or assumed. In actual statistical analyses it is seldom true that the structural relations of the economic model specify an exact functional relationship. We normally deal with stochastic rather than functional relations. Assuredly not all variables that might affect an economic relationship are included in the economic model specification, only the alleged most important variables are included. To allow for this incomplete specification statistically it is assumed that this disturbance random variable enters in to the structural relations of the statistical model.

Another concept important in this study is a <u>complete</u> <u>model</u>. Simply stated, it is a model that contains as many equations as there are endogenous variables. In general, complete models are required when we want to estimate the reduced form equations for prediction or for other analytical purposes. Also, from an economic viewpoint, a complete set of equations more clearly indicates the logic underlying the endogenous mechanism that is being modeled.

Once we have specified the statistical model, there remains at least one more critical consideration; namely, the identifiability of the structural parameters. The concept of _identification_ is briefly as follows. The structural parameters of a model are said to be identifiable if their values can be deduced from complete knowledge of the distribution function of the observations, or, in the case of a linear structural model (such as is specified in this study), from complete knowledge of the parameters of the reduced form. Identifiability is usually achieved in linear structural models by imposing _a priori_ restrictions on the values of the structural parameters, in particular by specifying that some parameters are zero. The restrictions may be such that the parameters in a given structural equation are _not identified (or under identified)_, _just identified_, or _over identified_. Sometimes just identified and over identified equations are referred to simply as _identified_. If all of the structural equations in a linear model are identified and if that model is complete, then the model is also said to be identified.

Koopmans has derived a necessary condition for the identifiability of a particular structural equation in a system of equations.[1] Let g be the number of endogenous variables appearing in the equation; let k be the number of predetermined variables appearing in the equation; and let K be the number of

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[1]Koopmans, T. C.: "Identification Problems in Economic Model Construction," in _Studies in Econometric Method_, Cowles Commission Monograph No. 14, W. C. Hood and T. C. Koopmans, editors, New York: John Wiley and Sons, 1953, Chapter II.

predetermined variables in the system of equations. Then the necessary condition for identifiability is $K-k \geq g-1$. I.e., if $K-k < g-1$, the equation is not identified. The equation may be said to be just identified or over identified (based on this condition) according as $K-k = g-1$ or $K-k > g-1$. Sufficient conditions for identifiability require values of population parameters which are unknown, but can be tested statistically.

Specification of the Economic Model

The economic model summarizes the economic specifications made by the analyst. A description of the variables and the structural relationships of the model will be discussed in this section. The specified model is formally complete and it contains ten relationships: eight behavioral equations and two identities.

Table 3.1 summarizes in a schematic form the ten endogenous variables, the twelve predetermined variables (including a constant term), and the ten specified relationships of the final form of the model (note that checks indicate included variables and that circled endogenous variables are selected as the normalizing variables). Definitions of all the variables are presented in Table 3.2.

The equations can be grouped as six equations pertaining to the cattle-beef sector and four pertaining to the other livestock-meat sector. Within each sector three major segments are

Table 3.1

SCHEMATIC SUMMARY OF THE ECONOMIC MODEL

	ENDOGENOUS										PREDETERMINED											
	PBEEFR	QBEEFC	POMEATR	PBEEFF	QBEEFP	IBEEFF2	POMEATF	IBEEFNF2	QOMEATC	QOMEATP	CONSTANT	DISPY	CMKTGM	IBEEFF1	IBEEFNF1	PPROTEIN	ARANGECI	POMEATFL	PFEEDIDL	QOMEATPL	NOMIMPORT	NBIMPORT
Equations:	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}	x_0	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
1. Demand for Beef at Retail	x	x	x								x	x										
2. Marketing in the Cattle-Beef Sector	x			x	x						x	x	x									
3. Supply of Beef Cattle at the Farm				x	x						x			x	x	x						
4. Inventory Demand for Beef Cattle Retained for Feeding at the Farm				x		x	x				x											
5. Inventory Demand for Beef Cattle Not-Retained for Feeding at the Farm				x				x			x				x		x					
6. Demand for Other Meat at Retail	x		x						x		x	x										
7. Marketing in the Other Livestock at the Farm			x				x			x	x	x	x									
8. Supply of Other Livestock at the Farm										x	x							x	x	x		
9. Other Livestock-Meat Sector Identity									x	x											x	
10. Cattle-Beef Sector Identity		x			x																	x
Sample Means	74.32	11466.8	60.43	19.53	11288.0	5583.6	20.46	47643.2	16311.3	16718.8	1.0	258.30	23.78	5325.0	45898.6	66.68	78.54	21.12	114.96	16213.5	-407.52	178.71

Table 3.2

DEFINITIONS OF VARIABLES

y_1	=	PBEEFR	: Price of BEEF at Retail deflated by CPI (Consumer Price Index, 1957-59=100); cents per pound
y_2	=	QBEEFC	: Quantity of BEEF Consumed, excluding veal (carcass weight); million pounds
y_3	=	POMEATR	: Price of Other MEAT at Retail (weighted average of pork, lamb and mutton, veal and poultry meat) deflated by CPI; cents per pound
y_4	=	PBEEFF	: Price of BEEF cattle at the Farm level deflated by PPFI (Prices Paid by Farmers Index, 1957-59=100); dollars per cwt.
y_5	=	QBEEFP	: Quantity of BEEF cattle Produced for slaughter (carcass weight); million pounds
y_6	=	IBEEFF2	: Inventory of BEEF cattle retained for Feeding at the end of the current period; thousand head
y_7	=	POMEATF	: Price of Other MEAT at the Farm level deflated by PPFI; dollars per cwt
y_8	=	IBEEFNF2	: Inventory of BEEF cattle Not-retained for Feeding at the end of the current period; thousand head
y_9	=	QOMEATC	: Quantity of Other MEAT Consumer (carcass weight); million pounds
y_{10}	=	QOMEATP	: Quantity of Other livestock (MEAT) Produced for slaughter (carcass weight); million pounds
x_0	=	CONSTANT	: A CONSTANT term identically equal to one
x_1	=	DISPY	: Consumers DISPosable income (Y) deflated by CPI; billion dollars
x_2	=	CMKTGM	: Cost of MarKeTinG Meat deflated by CPI; cents per pound
x_3	=	IBEEFF1	: (y_6 lagged), Inventory of BEEF cattle retained for Feeding at the beginning of the current period; thousand head
x_4	=	IBEEFNF1	: (y_8 lagged), Inventory of BEEF cattle Not-retained for Feeding at the beginning of the current period; thousand head
x_5	=	PPROTEIN	: Weighted Price of PROTEIN feeds deflated by PPFI; dollars per thousand pounds TDN (Total Digestible Nutrients).
x_6	=	ARANGECI	: Average (of August, September and October) RANGE Condition Index of the current period; reported as percent of normal
x_7	=	POMEATFL	: (y_7 lagged) Price of Other livestock (MEAT) at the Farm level, deflated by PPFI, Lagged; dollars per cwt.

Table 3.2 (con't)

x_8	=	PFEEDIDL :	Price of FEED InDex Lagged (1-year), deflated by PPFI, 1957-59=100
x_9	=	QOMEATPL :	(y_{10} lagged) Quantity of Other livestock (MEAT) Produced for slaughter Lagged (carcass weight); million pounds
x_{10}	=	NOMIMPORT :	(y_9 - y_{10}) Principally Net Other Meat IMPORTS (carcass weight); million pounds
x_{11}	=	NBIMPORT :	(y_2 - y_5) Principally Net Beef IMPORTS (carcass weight); million pounds

recognized: producer, marketing and consumer. That is, the demand relations at retail correspond to the behavior of consumers in the consumer segment; the marketing relationships corresponds to the behavior of firms in the marketing segment; and the supply equations at the farm correspond to the behavior of producers in the producer segment.

In addition, two inventory demand equations are postulated as also representing the behavior of producers in the producer segment of the cattle-beef sector. Finally, two identities are specified to account for differences in the levels of production and consumption in both the cattle-beef and the other livestock-meat sectors. The principal reason for a difference between these two variables (both measured in million pounds of carcass weight equivalents) has been the influence of the export-import movement of these meat commodities. The net level of imports for each is considered to be predetermined in this model, and the inclusion of the two identities serves to make the model formally complete.

1. Demand for Beef at Retail

From consumer demand theory, retail (consumer) demand for beef is postulated as a function of the price of beef, prices of close substitutes, prices of all other goods, consumers' income and the number of consumers. In this relation, the quantity of beef consumed (QBEEFC) and the average retail price of beef (PBEEFR) are specified as being jointly dependent (endogenous) variables. A weighted average retail price of other meat (POMEATR) is specified to reflect the prices of close substitutes, and it is also considered to be an endogenous variable in this study. Consumers' income is represented by an aggregate disposable income (DISPY) variable. A constant term is included in this relation (as will be the case for all the equations in the model).

The number of persons eating out of civilian food supplies was initially[2] specified to represent the number of consumers. However, in the final model this variable was not

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[2]Additional specifications were considered for all of the equations in the structural model. (We include some of the alternative specifications in Appendix A.) The final specifications presented here are, therefore, selections from sets of possible alternatives. We recognize that a type of statistical bias is introduced when a researcher arrives at a final specification by this procedure, but nevertheless we regard each specification of an equation as theoretically tractable, even though not unrelated to previous specifications.

included because of a high correlation (simple correlation coefficient .9913) between the disposable income and the population variables.[3] The well known problem of multicollinearity seemed obvious, so disposable income was specified to "represent" both variables whenever disposable income appears in an equation. Hence, in the fitted relationships the disposable income coefficient should be interpreted as the combined effects of these two variables. (The reader should note generally that no "trend terms" are specified in this model. Often times, researchers specify a time-variable to "explicitly" capture systematic effects, which may have been operative over the sample period, but which may not be explained by the included variables. On one hand this is an explicit, but arbitrary, way of recognizing that only the alleged most important variables have been specified. On the otherhand, due to the fact that time series data are often highly correlated with such a trend term, there is also the possibility of "purging-from" included variables, effects which may actually be due to those variables. But the reverse of this latter point is also plausible, i.e., trends in time

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[3] In Appendix A, we present an alternative specification of this demand equation using <u>per capita</u> disposable income and population as separate predetermined variables. We regard this alternative as one which might be preferred over our final specification and we recommend that research in this area consider further such a specification. It may be noted, however, that the simple correlation between per capita disposable income and population is also quite high: .9958 for the 1936-41, 1949-63 sample period.

series data may not be causal factors, thus a trend term might remove the "non-causal" influences of an explanatory variable which is spuriously correlated with "trends". We know of no general guiding rules in this regard, and our choice to omit trend terms is admittedly only one alternative. Some of the equations were also estimated including trend terms, as an alternative specification, and the results (using 2SLS) are reported in Appendix A.)

The above digression has a direct bearing on this particular equation, in that DISPY and a linear time variable, TIME, i.e., 1936=1, 1937=2, 1938=3,..., were simply correlated to the degree +.9953. Under such empirical conditions, we would hesitate to conclude that distinguishable individual (DISPY and TIME) effects were reliable even if "statistically significant" coefficient estimates were derived. (To a lesser, but substantial, degree TIME was simply correlated with other explanatory variables in this study, so that in each equation one or more specified variables are believed to have "captured" trend effects, which may or may not have been causal with regard to the specified variables).

Prices of "other goods" are represented indirectly by deflating all retail prices and other (non-farm) monetary variables with a consumer's price index (and farm price variables were deflated with a prices paid by farmers' index). Or, in other words, all monetary variables are expressed in "real" terms. This procedure seemed desirable given the period spanned by this study, i.e., 1936-41, 1949-63; and it is a generally accepted practice in cases where, for example, we believe that a doubling of all price and income variables would have no effect on consumption.[4]

So far the above discussion of the retail demand equation has led only to an implicit expression; namely (in the usual way of summarizing the relations implied by the economic model):

$$y_1^*, y_2, y_3; x_0, x_1 \qquad (1)$$

where y_1 = PBEEFR, y_2 = QBEEFC, y_3 = POMEATR, x_0 = CONSTANT, and x_1 = DISPY.

In this expression a comma should be read as "and," and a semicolon should be read "appear in relation with." The variables on the left of the semicolon are current endogenous variables and those on the right are considered predetermined within this particular model. (Most of the estimation methods used in this study require that a single endogenous variable in each equation be selected as a "normalizing variable"; the asterisk (*) in each relation indicates this normalizing variable.) The advantage of stating the economic model relations in this way is that we do not become involved in essentially statistical problems,

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[4] See, for example: Foote, R. J.: Analytical Tools for Studying Demand and Price Structures, Washington, USDA, Ag. Handbook No. 146, August 1958, p. 27.

e.g., stating the algebraic form of the relation, deciding whether or not to use actual data or logarithms, deciding how "disturbances" in the relations will be specified, and others.

2. Marketing in the Cattle-Beef Sector

When viewed in the aggregate, the composite behavior of firms in the marketing segment is conceived as representing, simultaneously, (1) a supply of beef (plus services) response at retail, and (2) a derived demand for beef cattle at the farm. The basic idea here is to postulate a single behavioral relation corresponding to the composite behavior of firms in the marketing segment of the cattle-beef sector. The derived demand at the farm (and consequent domestic supply of beef and services at retail) is further conceived as a function of (a) the "margin", (b) the costs of providing associated marketing services, (c) factors associated with shifts in the derived demand for beef, and (d) factors associated with shifts in the supply of services relative to the actual amount of meat products involved.

In terms of observable variables this relation is specified as the price of beef cattle at the farm (PBEEFF) being jointly determined with the price of beef at retail (PBEEFR). Both of these endogenous variables are in turn specified as being determined jointly with the quantity of beef produced for slaughter (QBEEFP). Consumers' disposable income (DISPY) is specified and considered to be a factor related both to shifts in the derived demand for beef cattle and to shifts in the supply of services (relative to actual meat supplies). Finally, an indicator of changing marketing costs is our CMKTGM (defined below) variable.

USDA sources publish a data series named the total meat marketing bill,[5] which is estimated by first dividing cash receipts for farm animals for slaughter by a market basket measure of the farm value of meat relative to the retail value for corresponding quantities. This provides an estimate of the retail value of all red meats, and the difference between the aggregate retail and farm values is then a marketing bill estimate. This measure (annual) was divided by total red meat consumption to get an (indicator) estimate of the cost of marketing meat per pound (CMKTGM), as used in this study. While the total meat marketing bill estimate (above) is broken down into components (e.g., labor costs, transportation costs, etc.), that which is not accounted for explicitly is classified as "other costs" (which includes profits to firms in the marketing industry). Hence, this variable (and our CMKTGM variable) includes some factors which are not really predetermined, thereby weakening our specification of CMKTGM as a predetermined variable. However, adequate data are not available for the desired "predetermined" components

[5]Derivations of marketing bill estimates are discussed in the following: Agricultural Marketing Service: "Farm-Retail Spreads for Food Products," USDA, Misc. Pub. No. 741, 1957, p.49.

over the entire sample period, and the CMKTGM variable seemed the best choice among the available alternatives.

A related concern was that using CMKTGM really implied "fitting" a near-identity relation, i.e., PBEEFF = PBEEFR - CMKTGM; but since the CMKTGM variable is based on all red meats, the identity does not of course hold exactly for any one. It is believed that this variable does capture major year-to-year changes in those costs of marketing, which are largely determined outside of the sectors being studied, and that the endogenous components are at least partially cancelled out by the process of averaging over all red meats. (Alternative specifications of this equation were attempted, including variables such as an average hourly wage index in the food marketing industry and a unit labor cost index for marketing farm food products,[6] but we regard the specification presented here to be the most suited given our preliminary findings.)

In summary, the composite marketing behavior relation of the cattle-beef sector is specified as follows:

$$y_1,\ y_4^*,\ y_5;\ x_0,\ x_1,\ x_2 \qquad (2)$$

where y_1 = PBEEFR, y_4 = PBEEFF, y_5 = QBEEFP, x_0 = CONSTANT, x_1 = DISPY, and x_2 = CMKTGM.

[6]These results (using 2SLS) are reported in Appendix A.

3. Slaughter Supply of Beef Cattle at the Farm

Total beef production in this study is considered as a flow into three components: slaughter, inventory of beef cattle for feeding purposes, and inventory of beef cattle for non-feeding purposes. We investigate and specify a structural equation for the slaughter supply response production - component here. Theoretically, we postulate that slaughter beef supply is in part a function of current period conditions (such as input and output prices, feed availability, weather, insitutional factors, and others); but that current slaughter is, also, in part a function of the producer decisions and commitments in previous periods.

In this slaughter supply of beef cattle structural relation the quantity of beef produced for slaughter (QBEEFP) and a farm price of beef cattle (PBEEFF) are specified as jointly determined, and PBEEFF is presumed to reflect current period (output) marketing conditions. The variable specified to account for feeding (input) conditions is price of protein feeds (PPROTEIN).[7] We specify PPROTEIN as an exogenous variable in

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[7]Other variables considered in alternative specifications included a price index of feed grains, available feed grains (excluding government carry-over, both for current and lagged periods), and available high-protein feeds. Some alternative specifications are reported in Appendix A.

this study[8] (but we do so with some uneasiness; ideally, we would have preferred to incorporate PPROTEIN, and/or other feed economy variables, as endogenous in an expanded system; data availability, increased "computational costs" and other factors precluded our doing so in this analysis.)

A major determinant of production capability in any given period, and hence indirectly of slaughter supply, is the level of beef cattle inventories at the beginning of the period. In this study, two aggregate inventory variables are considered; namely, the beginning (January 1) inventory on feed (IBEEFF1) and the beginning inventory not on feed (IBEEFNF1). We can think of IBEEFF1 and IBEEFNF1 as representing or summarizing the previous behavior of producers, in terms of the resources already committed to current (and future) production. Obviously, the specification of the two components rather than their sum implies a hypothesis that their respective effects on current slaughter beef supplies are not the same; and it seemed reasonable to expect a greater response per 1000 head of IBEEFF1 than from IBEEFNF1.

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[8] We regard the following factors as providing some support for our decision to specify PPROTEIN as an exogenous variable in this study: (a) high protein content feeds are used extensively in dairy rations throughout the United States, so PPROTEIN is not solely affected on the demand side by beef cattle and other meat production uses; (b) the impact of international trade increases the net elasticity of supply to domestic users; (c) feed grain price support programs have provided a "lower bound" exogenous effect on protein feed prices in most of the postwar period since protein feeds are close substitutes for feed grains; and (d) protein feeds are generally storable and hence can be carried from one period to another.

In summary, our specified slaughter supply of beef cattle relation is as follows:

$$y_4,\ y_5^*;\ x_0,\ x_3,\ x_4,\ x_5 \qquad (3)$$

where y_4 = PBEEFF, y_5 = QBEEFP, x_0 = CONSTANT, x_3 = IBEEFF1, x_4 = IBEEFNF1, and x_5 = PPROTEIN.

4. Inventory Demand for Beef Cattle Retained for Feeding at the Farm

In the description of the beef cattle production process (see Chapter II), we noted that beef feeding enterprises and cow-calf enterprises are largely separate operations; and also that the major producing areas for each type of enterprise differ regionally in the United States. Both of these factors led to a consideration of two separate inventory relations in the model. A third factor was that the two inventory components (lagged) are specified separately in the beef supply relation, i.e., relation 3, above.

The first of these inventory components to be explained is defined as the number of beef cattle held for feeding on farms at the end of the current period (IBEEFF2). The relation to be specified is referred to as a demand relation, but it is a demand relation for an "intermediate" commodity, i.e., a good which will serve as an input in a future production process. Theoretically, one would expect to consider factors such as the price of the commodity demanded, expected price of the finished product, prices of competing (substitute) commodities, expected costs of resources to be used in the production process, and factors associated with shifts in the demand relation.

These theoretical guidelines led to the specification of the price of beef cattle at the farm (PBEEFF) to represent both the price of feeders and the expected price of "finished" beef. The high correlation between an average price of feeders and PBEEFF (simple correlation coefficient = .9706) was the main reason for specifying PBEEFF in this case. Also, the current period PBEEFF was assumed to be a reasonable approximation of an expected price variable.[9]

Next, an average price of other livestock at the farm (POMEATF) was specified as representing competing farm enterprises. If, in fact, other livestock prices have influenced beef cattle producers' inventory decisions, then it seemed plausible that the major changes would be made in the IBEEFF2 level, -- since fed-beef producing enterprises would most likely compete with other livestock producing enterprises for the use of resources, e.g., feed, and possibly labor, capital, and equipment in areas where joint enterprises have been common. (Except for compe-

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[9] Several alternative specifications were tried in order to separate the effects described; for example, we considered both an average feeder cattle price series and an expected beef cattle price series (from Lerohl, M.: Ph.D. Thesis, Michigan State University, 1965, Expected Prices for U. S. Agricultural Commodities, 1917-62). We had difficulty obtaining statistical significance and plausible results. We believe the final specification is a meaningful and useful simplication.

tition in the use of the feed resource it is believed that a trend toward greater specialization in livestock production has lessened the direct impact of other livestock prices on fed-beef inventory decisions.) Changes in inventory levels, like slaughter supply (egn 3), are largely influenced by production capability, which in any given year is importantly affected by the beginning level of inventory, IBEEFF1. Or, viewed in a slightly different manner, IBEEFF1 reflects the previous period scale of feeding operations, and the level of IBEEFF2 is expected to be related to this summary measure of the previous behavior of producers.

Initially, alternative feed economy variables (e.g., available feed grains in the current period, PPROTEIN, and others) were specified as indicators of expected feeding conditions, but in this particular relation none of the variables considered contributed significantly (statistically) to the explanation of the specified endogenous mechanism. Thus, no other variables were included in the final specification.

The specified demand for beef cattle to be retained for feeding is summarized as follows:

$$y_4,\ y_6^*,\ y_7;\ x_0,\ x_3 \tag{4}$$

where y_4 = PBEEFF, y_6 = IBEEFF2, y_7 = POMEATF, x_0 = CONSTANT, and x_3 = IBEEFF1.

5. Inventory Demand for Beef Cattle Not-Retained for Feeding at the Farm

The second inventory equation is in principle quite similar to the first, i.e., equation 4; however, heavy concentrations of beef-cow and calf herds in the grassland and range areas of the United States limits, with respect to this relation, the degree of competition for resources between beef cattle and other livestock enterprises. Factors associated with the availability of roughage feeds are also considered to be of greater importance in this equation.

With these major differences in mind the number of beef cattle and calves not held for feeding on farms at the end of the current period (IBEEFNF2) is specified as being jointly determined with PBEEFF. The PBEEFF variable is believed to reflect both the price of the commodity demanded and an approximate expected price for non-fed beef cattle in a future period.

The beginning period inventory (IBEEFNF1) was included to reflect production capability, or scale of operation in the preceding period. Finally, an average (of August, September, and October) range condition index (ARANGECI) is specified to indicate the carrying capacity of ranges in the major cow-calf herd producing areas; and also to reflect implicitly the general availability of roughage feed which is a major input in the cow-calf production process.

The economic specification of the inventory demand for beef cattle not-retained for feeding is summarized as follows:

$$y_4,\ y_8^*;\ x_0,\ x_4,\ x_6 \qquad (5)$$

where y_4 = PBEEFF, y_8 = IBEEFNF2, x_0 = CONSTANT x_4 = IBEEFNF1, and x_6 = ARANGECI.

6. Demand for Other Meat at Retail

This relation is specified symmetrically to the demand for beef meat (relation 1). The price of other meat at retail (POMEATR) and the quantity of other meat consumed (QOMEATC) are considered to be jointly determined in this relation, with the price of beef at retail (PBEEFR) specified to reflect the influence of close substitutes, and consumers' income represented by the disposable income variable (DISPY). As before, DISPY also reflects the impact of the number of consumers on demand, because the population variable and DISPY were highly correlated over the sample period.

The specified demand for other meat at retail relation is summarized as follows:

$$y_1,\ y_3^*,\ y_9;\ x_0,\ x_1 \qquad (6)$$

where y_1 = PBEEFR, y_3 = POMEATR, y_9 = QOMEATC, x_0 = CONSTANT, and x_1 = DISPY.

7. Marketing in the Other Livestock-Meat Sector

Except for poultry and poultry meat, the marketing segment of the other livestock-meat sector is basically not much different functionally or operationally from the cattle-beef sector marketing segment. Assuredly, there are important differences but in aggregate studies of this kind it is difficult to account for more than the dominant attributes of the segments involved. Consequently, the same conceptual framework was employed to represent the aggregate behavior of firms in the marketing segment of the other livestock-meat sector as was described above (see relation 2) for the cattle-beef sector.

Thus, as one relationship, the endogenous mechanism includes both the price of other meat at retail (POMEATR) and the price of other livestock at the farm (POMEATF) as jointly dependent variables; and these variables are further considered to be jointly determined with the quantity of other livestock produced for slaughter (QOMEATP).

Disposable income (DISPY) is specified to reflect shifts in the derived demand for other livestock and also shifts in the supply of marketing services associated with a given level of other livestock-meat. The cost of marketing meat per pound (CMKTGM) is specified to account for effects of changing costs of marketing on the endogenous mechanism of this relationship.

In summary, the specified marketing behavior relation in the other livestock-meat sector is as follows:

$$y_3,\ y_7^*,\ y_{10};\ x_0,\ x_1,\ x_2 \qquad (7)$$

where y_3 = POMEATR, y_7 = POMEATF, y_{10} = QOMEATP, x_0 = CONSTANT, x_1 = DISPY, and x_2 = CMKTGM.

8. Supply of Other Livestock at the Farm

The theoretical basis for the supply relation postulated here involves a rather straight-forward application of a distributed lag model, such as has been developed by Nerlove.[10] This model will be developed here both to present the logic underlying the final postulated supply relation, and to specify a relationship which itself has a quite practical usefulness.

Let us assume that current output Q_t is a simple function of an expected product price, P_t^{1*}, and of an expected input price (cost), P_t^{2*}, so that:

$$Q_t = a + bP_t^{1*} + cP_t^{2*}. \tag{i}$$

Now consider the following assumption about how producers might reasonably form the above price expectations, P_t^{i*}. Let

$$P_t^{i*} - P_{t-1}^{i*} = \gamma(P_{t-1}^{i} - P_{t-1}^{i*}), \tag{ii}$$

which is to stay that the current expected price (P_t^{i*}) differs from the previous period expected price (P_{t-1}^{i*}) by a constant proportion (γ)[11] of the difference between the actual previous period price (P_{t-1}^{i}) and the previous period expected price (P_{t-1}^{i*}). Rewrite this expression to obtain:

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[10]Nerlove, M.: "Distributed Lags and the Estimation of Long-Run Elasticities of Supply and Demand: Theoretical Considerations," Journal of Farm Economics, Vol. 40, May 1958; and also: Distributed Lags and Demand Analysis for Agricultural and Other Commodities, Washington: USDA, Ag. Handbook No. 141, 1958.

[11]Note that this assumes the same expectation coefficient γ for output and input prices.

$$P_t^{i*} = \gamma(P_{t-1}^{i} - P_{t-1}^{i*}) + P_{t-1}^{i*}$$

$$= \gamma P_{t-1}^{i} + (1-\gamma)P_{t-1}^{i*} \qquad \text{(iii)}$$

Substitute P_t^{i*} from (iii) in (i) to obtain:

$$Q_t = a + b\,[\gamma P_{t-1}^{1} + (1-\gamma)P_{t-1}^{1*}] + c\,[\gamma P_{t-1}^{2} + (1-\gamma)P_{t-1}^{2*}] \qquad \text{(iv)}$$

Similarly, express Q_{t-1} as:

$$Q_{t-1} = a + bP_{t-1}^{1*} + cP_{t-1}^{2*}. \qquad \text{(v)}$$

Now multiply Q_{t-1} by $(1-\gamma)$ and subtract from Q_t. The result can easily be shown to simplify to the following

$$Q_t = \gamma a + \gamma bP_{t-1}^{1} + \gamma cP_{t-1}^{2} + (1-\gamma)Q_{t-1}$$

$$= d_1 + d_2P_{t-1}^{1} + d_3P_{t-1}^{2} + d_4Q_{t-1} \qquad \text{(vi)}$$

Relation (vi) is identical to the type of function that is specified in this study. This relation will now be stated in terms of the variables used in this study. The quantity of other livestock produced for slaughter at the farm (QOMEATP) is considered the endogenous (dependent) variable in this relation; and it is specified as a function of the lagged (1 year) price of other livestock at the farm (POMEATFL), the lagged price index of feed grains (PFEEDIDL), and the lagged quantity of other livestock produced for slaughter at the farm (QOMEATPL).

The reader might note here that the d_i $(i = 1,\ldots,4)$ coefficients are estimated in this study; but from these estimates it is possible to derive estimates of a, b, c, and γ in relation (i), i.e., $a = \frac{d_1}{1 - d_4}$, $b = \frac{d_2}{1 - d_4}$, $c = \frac{d_3}{1 - d_4}$ and $\gamma = 1\text{-}dy$.

The d_i are termed structural form parameters and they indicate the direct effect of their corresponding variables on Q_t. In contrast, a, b, and c are coefficients which are assumed to represent the long run influences of the expected prices on current output. Thus, estimates of both the short run and the long run supply response function for other livestock are obtained. (The presentation and analysis of these estimates are discussed in the empirical results chapter).

Also, note that only one endogenous variable (QOMEATP) appears in this relation, and consequently, the OLS method of estimation is applicable in this case.

In summary, the specified supply of other livestock at the farm relation is as follows:

$$y^*_{10} \; ; \; x_0, x_7, x_8, x_9 \qquad (8)$$

where y_{10} = QOMEATP, x_0 = CONSTANT, x_7 = POMEATFL, x_8 = PFEEDIDL, and x_9 = QOMEATPL.

9. Other Livestock-Meat Sector Identity

In this study the levels of domestic other livestock production for slaughter (QOMEATP) and domestic other livestock-meat consumption (QOMEATC) are treated as separate endogenous variables, although both variables are measured in million pounds of carcass weight equivalent. The difference in the levels has been principally due to net shipment of other livestock commodities out of the U. S. market in the recent past; or, in any case, due to international trading. Also, military supplies are deducted from the total slaughter level prior to estimating the amount consumed by the population eating out of civilian food supplies; and a small part of the difference has been due to changes in commercial storage holdings from one period to the next.

To a considerable extent each of these "alternative markets" has been subject to institutional factors which are determined outside of the system being considered. Thus, the difference between QOMEATC and QOMEATP is specified as being predetermined; and for simplicity, defined as net other meat imports (NOMIMPORT).

Based on the above considerations the following identity is specified:

$$\text{QOMEATC} - \text{QOMEATP} \equiv \text{NOMIMPORT}$$

Of course, no coefficient estimates need be determined in this relation.

In the summary notation used previously, this postulated other livestock-meat sector identity is specified as follows:

$$y_9, y_{10}; x_{10} \tag{9}$$

where y_9 = QOMEATC, y_{10} = QOMEATP, and x_{10} = NONIMPORT. However, the economic specification includes the assumption that the coefficients are $\pm$ 1, i.e., such that $y_9 - y_{10} \equiv x_{10}$.

10. Cattle-Beef Sector Identity

International trading, military consumption and changes in commercial storage stocks are likewise factors which have caused a divergence in the level of beef cattle production for slaughter (QBEEFP) and the level of beef-meat consumption (QBEEFC). Again, international trade has been the dominant component; and, also, the amount of beef movement through these alternative channels has been determined largely by institutional and other conditions outside the system.

Consequently, a cattle-beef sector identity is specified as

$$\text{QBEEFC} - \text{QBEEFP} \equiv \text{NBIMPORT}$$

where NBIMPORT was defined as this difference.

In the format thus far used, the cattle-beef sector identity is specified as follows:

$$y_2,\ y_5;\ x_{11}\ , \tag{10}$$

or more specifically as

$$y_2 - y_5 \equiv x_{11}$$

where y_2 = QBEEFC, y_5 = QBEEFP, and x_{11} = NBIMPORT.

The above 10 relations, taken as a system of relations, complete the specification of the economic model. Next, the statistical specifications of the overall model (and of the alternative estimators) are discussed; and the combined economic and statistical specifications are then summarized in terms of a statistical model.

The Statistical Model

All the structural relations are specified as linear in the variables and linear in the parameters. That is, each relation, i ($i = 1,2,\ldots,10$), can be represented as follows:

$$\alpha_{i1}y_1(t) + \ldots + \alpha_{ig}y_g(t) + \ldots + \alpha_{i,10}y_{10}(t) + \beta_{i0}x_0(t) + \ldots + \beta_{ik}x_k(t) + \ldots + \beta_{i,11}x_{11}(t) + u_i(t) = 0 \qquad (1)$$

where α_{ig} and β_{ik} are the structural form coefficients to be estimated, y_g and x_k are the specified observable economic variables, and $u_i(t)$ is a random disturbance term. From the economic model the y_g and x_k that enter a particular equation are known; and for those not specified, the corresponding α_{ig} and β_{ik} are assumed to be zero.

The above equations are assumed to hold for each period t ($t = 1,2,\ldots,T$). Since the economic relations are specified to include only the theoretically most important variables, we do not expect the relations to hold exactly. Thus, the inclusion of $u_i(t)$ is required in the statistical specifications in order to operationalize the estimation procedures. Other properties regarding the distribution of $u_i(t)$ must be specified (or assumed) however, and these assumptions are stated below.

In matrix and vector notation the overall structural form can be represented as follows:

$$A\ \bar{y}(t) + B\ \bar{x}(t) + \bar{u}(t) = 0 \quad (t=1,\ldots,T) \qquad (2)$$

where $A = [\alpha_{ig}]$ $(i,g=1,\ldots,10)$, $B = [\beta_{ik}]$ $(k=0,1,\ldots,11)$, $\bar{y}(t) = [y_1^{(t)},\ldots,y_{10}^{(t)}]'$, $\bar{x}(t) = [x_0^{(t)},\ldots,x_{11}^{(t)}]'$, and $\bar{u}(t) = [u_1^{(t)},\ldots,u_{10}^{(t)}]'$.

Note that (2) refers to only a single joint observation. To write the system in terms of all observations we can define:

$$\underset{(GxT)}{Y} = [\bar{y}(1),\ldots,\bar{y}(t),\ldots,\bar{y}(T)],$$

$$\underset{(KxT)}{X} = [\bar{x}(1),\ldots,\bar{x}(t),\ldots,\bar{x}(T)], \quad \text{and}$$

$$\underset{(GxT)}{U} = [\bar{u}(1),\ldots,\bar{u}(t),\ldots,\bar{u}(T)],$$

where $\bar{y}(t)$, $\bar{x}(t)$ and $\bar{u}(t)$ are defined above. With these definitions the structural form model, in terms of all T observations can be written compactly as

$$AY + BX + U = 0 \qquad (3)$$

where A is of order (GxG) (G = 10 in this particular model), y is (GxT) (T = 21), B is (GxK)(K = 12), X is (KxT), and U is (GxT).

At this point it is convenient to derive the reduced form relations, which are derived from the structural form model when the model is complete. Starting with (2) we can write

$$A^{-1}A\ \bar{y}(t) + A^{-1}B\ \bar{x}(t) + A^{-1}\bar{u}(t) = 0$$

or

$$I\ \bar{y}(t) + \Pi\ \bar{x}(t) + \bar{v}(t) = 0 \qquad (4)$$

where $\bar{v}(t) = [v_1(t),\ldots,v_g(t),\ldots,v_{10}(t)]'$.

Again this expression represents only a single joint observation but note the rows represent each y_g as a function of only predetermined variables plus a disturbance term v_g. Now, to write the system compactly in terms of all observations we can apply the same procedure, such that

$$A^{-1}AY + A^{-1}BX + A^{-1}U = 0$$

or $$IY + \Pi X + V = 0 \qquad (5)$$

where Π is of order (GxK) and V is (GxT). One can note that the t-th column of (5) is indeed the set (4) above.

In a nutshell, the primary objective from this point on was to obtain estimates of the structural form parameters which are implicitly specified in the matrices A and B in (3) above, and estimates of the reduced form parameters in Π in (4). The structural model is again summarized in Table 3.3 below, but with the emphasis here to note explicitly the structural form coefficient parameters which are specified and estimated (or assumed) in this study.

The combined economic and statistical specifications thus far presented can now be conveniently summarized:

a) $A\,\bar{y}(t) + B\,\bar{x}(t) + \bar{u}(t) = 0 \;(t = 1,\ldots,T)$,

b) A is nonsingular (assumed),

c) Certain elements of A and B are known to be zero, and

d) Certain rows of A and B are known, *a priori* (and the corresponding relations are called identities).

Table 3.3

SCHEMATIC SUMMARY OF THE STATISTICAL MODEL

VARIABLES	ENDOGENOUS										PREDETERMINED											
	PBEEFR	QBEEFC	POMEATR	PBEEFF	QBEEFP	IBEEFF2	POMEATF	IBEEFNF2	QOMEATC	QOMEATP	CONSTANT	DISPY	CMKTGM	IBEEFF1	IBEEFNF1	PPROTEIN	ARANGECI	POMEATFL	PFEEDIDL	QOMEATPL	NOMIMPORT	NBIMPORT
Relations	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}	x_0	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
1. Demand for Beef at Retail	-1	α_{12}	α_{13}								β_{10}	β_{11}										
2. Marketing in the Cattle-Beef Sector	α_{21}			-1	α_{25}						β_{20}	β_{21}	β_{31}									
3. Slaughter Supply of Beef Cattle at the Farm				α_{34}	-1						β_{30}			β_{33}	β_{34}	β_{35}						
4. Inventory Demand for Beef Cattle Retained for Feeding at the Farm				α_{44}		-1	α_{47}				β_{40}			β_{43}								
5. Inventory Demand for Beef Cattle Not Retained for Feeding at the Farm				α_{54}				-1			β_{50}				β_{54}		β_{56}					
6. Demand for Other Meat at Retail	α_{61}		-1						α_{69}		β_{60}	β_{61}										
7. Marketing in the Other Livestock-Meat Sector			α_{73}				-1			$\alpha_{7,10}$	β_{70}	β_{71}	β_{72}									
8. Supply of Other Livestock at the Farm										-1	β_{80}							β_{87}	β_{88}	β_{89}		
9. Other Livestock-Meat Sector Identity									-1	1											1	
10. Cattle-Beef Sector Identity		-1			1																	1

Some additional statistical specifications which will be assumed generally, are the following (see Goldberger[12]):

e) $E[\bar{u}(t)] = 0 \quad (t = 1,\ldots,T)$, or $E[U] = 0$, i.e., the random error or disturbance term has an expected value of 0 for each relation i, and for each period t.

f) $E[\bar{u}(t)\bar{u}'(t)] = \Sigma \quad (t = 1,\ldots,T)$, where Σ is a (GxG) nonnegative definite matrix, i.e., the contemporaneous covariance matrix of disturbances in the different equations is the same for all t (but note that Σ is not assumed to be diagonal).

g) $E[\bar{u}(t)\bar{u}'(t)] = 0 \quad (t,t' = 1,\ldots,T;\ t \neq t')$, i.e., the disturbance factor is temporally uncorrelated, or all lagged covariances between disturbances in the same or different equations are zero.

h) It is assumed that the predetermined variables are generated by a stationary multivariate stochastic process with nonsingular contemporaneous covariance matrix Σ_{XX} and that any dependence in the process is sufficiently weak so that (taking the variable as deviation from means)

$$\text{plim}\ T^{-1} \Sigma_{t=1}^{T} \bar{x}(t)\ \bar{x}'(t) = \Sigma_{XX}$$

i) Further, it is assumed that the process generating the predetermined variables is contemporaneously uncorrelated with the process generating the disturbances, so that

$E[\bar{x}(t)\ \bar{u}'(t)] = E[\bar{x}(t)]\ E[\bar{u}'(t)] = 0$, and that any dependence in each of the processes is sufficiently weak such that $\text{plim}\ \Sigma_{t=1}^{T} \bar{x}(t)\ \bar{u}'(t) = 0$, or $\text{plim}\ \Sigma\ T^{-1} X'U = 0$, i.e., $\text{plim}\ \Sigma_{t=1}^{T} x_k(t)\ u_g(t)/T = 0$ for all k and g. This specification (assumption) captures the idea that the predetermined variables are <u>not</u> determined by the system at time t and thus are not dependent on the disturbances at time t.

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[12] Goldberger, A. S.: Econometric Theory, New York: John Wiley and Sons, 1964, pp. 299-306.

Goldberger discusses these "generalized" statistical assumptions and one of the main reasons for introducing them is the presence of lagged endogenous variables among the set of predetermined variables. For example, exogenous variables may be distributed independently of all disturbances or simply uncorrelated with the contemporaneous disturbances; but lagged endogenous variables are assumed to be distributed independently of contemporary and succeeding disturbances, which is a stronger assumption than being merely uncorrelated. In any case, the specification of i) and h) above in terms of stationary stochastic processes is adequately general for denoting the necessary statistical assumptions in this study.

j) Finally, in each structural equation, the coefficient of one jointly dependent (endogenous) variable may be taken as -1, a priori, i.e., a normalizing variable for each relation i (i = 1,...,10), for which the corresponding α_{ig*} is taken to be -1.

The implication of the procedure described in J) is that the coefficients α_{ig} and β_{ik} are actually estimated only up to a factor of proportionality relative to α_{ig*}; and by assuming $\alpha_{ig*} = -1$, then y_{g*} is in effect explicitly stated as a function of the other endogenous and predetermined variables in the equation.

Some Theoretical Comparisons of the Estimators Used in this Study

Given the above set of statistical assumptions, i.e., (a),...,(j), one can note some of the theoretical differences between the alternative estimators used in this study. First, consider the structural relations (after normalizing) in the form:

$$y_{ig^*} = \Sigma_{g \neq g^*} \alpha_{ig} y_g + \sum_k \beta_{ik} x_k + u_i ,$$

so that on the right-hand side there are both endogenous (y_g) and predetermined (x_k) variables. This form appears similar to the usual way of denoting a linear regression equation. However, because there are current endogenous variables on the right-hand side, which are in general not independent of the disturbance term, OLS coefficients are not even consistent estimates of the structural parameters (α's and β's).

The 2SLS procedure, in essence, results in replacing the right-hand side endogenous variables (y_g, $g \neq g^*$) with "appropriate" estimates of y_g which has been shown to establish the consistency of the 2SLS estimators. The 2SLS procedure was developed by Theil, and also independently by Basmann.[13] Theil has shown, further, that 2SLS is a special case of a whole family of (k)-class estimators. The UNK method in this study is one other special case of the (k)- class family of estimators, which has been proposed by Nagar.[14] The k-value of the UNK estimator has plim (k-1) = 0, and this property establishes, in general, the asymptotic property of consistency for that (k)-

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[13]See Theil, H.: op.cit., 1961; and, Basmann, R. L.: op.cit., 1957.

[14]Nagar, A. L.: op.cit., 1959.

class estimator.

The LISE procedure was developed prior to the 2SLS and (k)-class procedures by Anderson and Rubin.[15] Their approach is an application of the maximum likelihood principle under the specification that the structural disturbances are normally distributed and utilizing only restrictions on the structural relation being estimated. Under the normality assumption, estimates are consistent and are also asymptotically normal and efficient.[16] However, Theil has shown that LISE estimators are members of the (k)-class family, and hence consistent, with or without the normality assumption.[17]

Finally, the 3SLS procedure, as developed by Zellner and Theil,[18] is a system method of estimation, i.e., a "full information" method which makes use of restrictions on the parameters of the full system in estimating each structural relation; and it is a system method in that all the structural relations are estimated simultaneously. 3SLS is a consistent

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[15] Anderson, T. W. and Rubin, H: op.cit; see also: Chernoff, H. and Rubin, H.: "Asymptotic Properties of Limited Information Estimates Under Generalized Conditions," in Studies in Econometric Method, W. C. Hood and T. C. Koopmans, editors, op.cit., 1953, pp. 200-212.

[16] For definitions of these terms, see, for example: Koopmans, T. C. and Hood, W. C.: "The Estimation of Simultaneous Economic Relationships," in Studies in Econometric Method, W. C. Hood and T. C. Koopmans, editors, op.cit., 1953, pp. 128-131.

[17] Theil, H.: op.cit., 1961, pp. 231-232, 334-336.

[18] Zellner, A. and Theil, H.: op.cit., 1962.

estimator provided the "starting" estimates are consistent; and since more information regarding the system is utilized, the 3SLS method is asymptotically efficient relative to the "limited information" procedures described above.

This very brief summary of the properties of the alternative estimators is perhaps sufficient to indicate that the principal theoretical differences are based on asymptotic properties. We know only a limited amount about small sample characteristics of the alternative estimators as indicated primarily from Monte Carlo studies.[19] Among the methods employed herein, the 3SLS procedure is presumably the most suited estimation method from the standpoint of asymptotic efficiency. However, one should note that it is generally believed that the system methods (e.g., 3SLS and Full Information Maximum Likelihood) may be more sensitive than single-equation methods to specification errors in the model as a whole.

Sample Period and Data

Annual time series data for 1936-41, 1949-1963 were used for this study. The main reasons for excluding observations prior to 1936 were non-availability of data series for some variables used in this study (particularly prior to 1930), the

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[19] For a summary of much of the Monte Carlo studies to date, see: Johnston, J., <u>op.cit</u>., 1963, Chapter 10, pp. 275-295.

abnormal relationships due to the general economic depression (and drouth) in the early 1930's (including processing taxes levied on meat packers from 1933-1935), and important structural changes (in general, throughout the consumer, marketing and producer segments), many not having occurred until the late 1930's. Observations for the war years, 1942-1946, were excluded because of abnormal relationships (due partly to price controls and rationing in the meat economy); and 1947-1948 observations were also considered to reflect abnormal conditions due to adjustment lags, especially in the cattle-beef sector (actually, some 1948 data are used because lagged variables are specified). From a positive standpoint, the sample period is presumed to reflect a "normal" period (generally a period of economic growth with price relationships determined in the marketing system, albeit price supports of some farm feed commodities have prevailed throughout the postwar period). U. S. annual time series (secondary) data were obtained primarily from the records of government departments and agencies. The actual data used are presented in Appendix C, where specific sources for the series used are also cited. The data were accepted as accurate without allowances for errors of observation having been made in the estimation procedures.

CHAPTER IV

EMPIRICAL RESULTS

In the first section of this chapter, the structural form coefficient estimates obtained from the alternative estimators are presented and discussed. In addition, a number of other statistics are presented which are useful for evaluating the fitted relations; namely, estimated standard errors of the coefficients, k-values, coefficients of determination (R^2's), and Durbin-Watson statistics. For all the estimators except OLS, standard errors are based on asymptotic formulas. The R^2's and the Durbin-Watson statistics have been developed for OLS estimation, but the same formulas were used to calculate similar statistics for the simultaneous equations methods. Since we focus on a particular endogenous variable (due to normalizing) in each relation, there is an intuitive appeal to interpret these statistics in the usual manner; however, in all but the OLS procedure, the reader should note that the R^2's and the Durbin-Watson statistics are not strictly applicable. Nevertheless, it is felt that these statistics do provide additional comparisons among the alternative estimators.

The following sections include additional analyses of the fitted structural equations (tests of identifiability of the structural relations, the long run slaughter beef supply implications of our estimated producer-segment structural equations, and conditional explanations of the normalizing endogenous variables over the sample period); then the implications of the reduced form estimates as forecasting mechanisms are considered; and finally, some comparisons of estimates from this study with related statistics from other studies are discussed. The main purposes of this chapter are to present the main findings of this study and to relate our results to other relevant research results.

As stated in the Introduction, six alternative estimators were employed: (1) 3SLS, (2) 2SLS, (3) UNK, (4) LISE, (5) OLS, and (6) I3SLS. Zellner and Theil recommend that 2SLS estimates be used as starting estimates for 3SLS (to be referred to as 3SLS(2SLS)); however, the only property required of the starting estimates is that they be consistent; so, for comparative purposes, the 3SLS procedure is applied using UNK and LISE beginning estimates (and these estimates are referred to, respectively, as 3SLS(UNK) and 3SLS(LISE). "Converged" I3SLS estimates are presented, but no evaluation is attempted at this time. It is noteworthy that the I3SLS estimates beginning with 2SLS, UNK, and LISE estimates did converge in each case to the same values for all coefficients estimated (although, relatively faster when started with 2SLS).[1]

Structural Form Parameter Estimates

For convenience in discussing the results, the 3SLS(2SLS) estimates are generally interpreted in the greatest detail, with comparative statements made regarding the other estimates. Summary tables of the statistics presented are included for each equation on the page immediately following the introduction of the respective equation. A standard table format is used throughout. Namely, the estimated structural coefficients are listed first, and their estimated standard errors are directly beneath; k-values are presented whenever applicable (otherwise denoted by n.a. meaning not applicable); R^2's (coefficients of determination calculated as if the equation had been fit by OLS) and D. W. (Durbin-Watson) statistics complete the information presented in the tables. The D. W. statistics are generally used to test for autocorrelation (serial correlation) of the disturbances in regressions, but since the basic assumptions for applying the Durbin-Watson tables are violated by the

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[1]The I3SLS(2SLS) procedure was applied for 200 interations (2.83 seconds per iteration) and the coefficient estimates were "converged" (in terms of a maximum absolute change ratio, for <u>any</u> coefficient, from the preceding iteration, to the order of 10^{-9}). The I3SLS(UNK) and I3SLS(LISE) procedures were each applied for 100 iterations and the coefficient estimates were equivalent to the number of decimal places reported (for each of the procedures). The estimates were obviously converging to the same limits irrespective of the starting estimates used, i.e., either 2SLS, UNK or LISE.

nature of our equations and/or estimation procedures, we do not present any test results, but simply give the statistics themselves for descriptive or comparative purposes. (It may be noted that a D. W. statistic value less than 2 is an indication of positive serial correlation in the calculated (sample) residuals, while a value greater than 2 is an indication of negative serial correlation.)

1. Demand for Beef at Retail[2]

Using 3SLS(2SLS), the estimated coefficient of each variable in the demand for beef at retail relation has its expected sign and is statistically significant.[3] The coefficient of QBEEFC is negative (-.00676) thus indicating that increases in the level of beef consumption are associated with lower retail

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[2]The single equation results reported here for this equation (2SLS, UNK, LISE) were computed with NBIMPORT not included in the set of predetermined variables in the system. (All 3SLS computations, however, included all the predetermined variables in the system.) The resulting single equation estimates have nearly the same asymptotic properties as would estimates computed with NBIMPORT included (in particular, they are consistent, but presumably somewhat less efficient). The 2SLS estimates for this equation were recomputed with NBIMPORT included (in the set of predetermined variables in the system), a similar recomputation was also done for a corresponding reason on equation 6, and the resulting 3SLS(2SLS) estimates for all equations were also obtained. These results are summarized in Appendix E. In all cases the actual numerical coefficients obtained differ only negligibly from those reported here.

[3]An estimated coefficient will be said to be "statistically significant" or "significantly different from zero" when the ratio of the coefficient to its standard error is 2 or greater. This corresponds roughly to an (asymptotic) significance level of about 5%.

Table 4.1

DEMAND FOR BEEF AT RETAIL: COEFFICIENT ESTIMATES AND RELATED STATISTICS[a]

	PBEEFR	QBEEFC	POMEATR	CONSTANT	DISPY	K	R^2	D.W.
a) 3SLS(2SLS)	-1.0	-.00676	.4713	28.92	.3654	n.a.	.9322	1.18
		.00077	.1089	7.55	.0322			
b) 2SLS	-1.0	-.00744	.3357	38.40	.3910	1	.9363	1.26
		.00090	.1348	9.29	.0376			
c) UNK	-1.0	-.00746	.3274	38.93	.3914	1.29	.9361	1.27
		.00090	.1349	9.30	.0377			
d) LISE	-1.0	-.01726	-1.2755	148.04	.7790	3.69	.0852	1.08
		.01059	1.7228	117.36	.4211			
e) OLS	-1.0	-.00744	.3572	37.01	.3910	0	.9364	1.24
		.00080	.1179	8.16	.0336			
f) 3SLS(UNK)	-1.0	-.00676	.4675	29.17	.3654	n.a.	.9324	1.19
		.00077	.1088	7.54	.0322			
g) 3SLS(LISE)	-1.0	-.00933	.1715	51.06	.4642	n.a.	.9141	1.16
		.00263	.3943	27.02	.1115			
h) I3SLS	-1.0	-.00667	0.4571	29.63	.3621	n.a.	.9322	1.20
		.00070	0.0941	6.51	.0300			

[a]Table format and symbols are discussed at the beginning of the section.

beef prices, as expected. This coefficient implies a structural form elasticity of PBEEFR with respect to QBEEFC of -1.043, i.e., a 1 percent change (increase) in level of beef consumption is associated with a 1.043 percent change (decrease) in the average beef price (calculated at the sample means). For brevity (and accuracy) we introduce the following symbolic notation for reference to our estimated structural form elasticities (which are considered frequently throughout this discussion): ε (PBEEFR/QBEEFC) = —1.043. Thus, ε refers to an elasticity; the first named variable is considered "dependent"; and we are denoting the structural effect (or direct effect)[4] as a percentage change in the dependent variable "with respect to" (/) a 1 percent change in the second named variable which is considered "independent". We further make the usual <u>ceteris paribus</u> assumption that all other variables are being held constant (at their mean levels).

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[4]Throughout this Chapter reference will be made to structural form "direct effect" and reduced form "total effects" of a given predetermined variable on the current normalizing endogenous variable. The following remarks from Goldberger, A.S.: <u>Econometric Theory</u>, New York: John Wiley and Sons, 1964, p. 369, may help clarify and justify the interpretations presented. "A particular reduced-form coefficient π_{km} may then be interpreted as the partial derivative (of the conditional expectation) of the current endogenous variable y_{tm} with respect to the predetermined variable x_{tk} with all other x_t's held constant. Thus the reduced-form coefficient indicates the 'total' effect of a change in x_{tk} on (the conditional expectation of) y_{tm} after taking account of the interdependences among the current endogenous variables; a similar economists' word for such a coefficient is "multiplier'. In contrast, a structural coefficient indicates only a direct effect within a single sector of the economy."

The coefficient estimate for POMEATR is positive, thus indicating that an increase (say) in the POMEATR is associated with an increase in the PBEEFR (as is expected for "substitutes" in consumption). The corresponding ε(PBEEFR)/POMEATR) = +.383.

The 3SLS(2SLS) DISPY coefficient estimate is positive and highly significant. An ε(PBEEFR/DISPY) = +1.270, was derived, but it should be recalled that DISPY was specified to represent the combined effects of disposable income and population (and possibly a linear "trend). (Alternative specifications of this relation, including population and a trend term as separate variables, are presented in Appendix A; and estimated by 2SLS.

Since the 3SLS(2SLS) reduced form estimates (for all endogenous variables in the system) were calculated for the model, another type of elasticity estimate (for the predetermined variables as the "independents") is obtainable; namely a reduced form elasticity which represents the "total effect" of a predetermined variable (on a particular endogenous variable) after account has been taken of the interdependencies among the current endogenous variables. Such an estimate is commonly called a "multiplier". Symbolically, we will denote such elasticities by adding a superscript "T" to our previous code, e.g., ε^T (PBEEFR/DISPY) = +3.277, where "T" means a total effect (in the sense described).[5] We do not attempt to

[5] Also see footnote 3 above.

appraise the reliability of these estimates. (One reason is that reduced form coefficient standard error estimates were not derived, and another is that the main emphasis of this study is on a structural estimation). Pending further study in this area, our reduced form elasticity estimates should perhaps receive only casual attention.

The 3SLS estimates differ rather substantially (in this particular equation) from the other estimates; however, 2SLS, UNK and OLS estimates are quite similar when compared only among themselves (and they are statistically significant, with signs as expected). The LISE estimates are decidedly poorer in that none of the estimates in this relation are statistically significant, their magnitudes are considerably different from any of the other estimators, and the POMEATR coefficient has an unexpected sign. Note that k=3.69, which is substantially larger than its asymptotic limit of 1. The "R^2" = .0852 also indicates that this fitted relation explains very little of the variation in PBEEFR (but again, this R^2 is calculated as if the relation had been fit by OLS).

A high k-value (or equivalently a high least variance ratio, or a large minimum characteristic root of the appropriate determinantal equation) in LISE indicates (in general) that high correlations exist between included endogenous variables (or a linear combination thereof, in particular that linear combination estimated) and excluded predetermined variables (or a linear combination thereof, in particular that linear combination estimated in the denominator of the least variance ratio). We cannot say, <u>a priori</u>, whether a high k-value will result in a substantial influence on the estimates (relative to other k-class estimators) in a particular specified structural equation. However, once a relatively high k-value is actually obtained from employing LISE, then it becomes of interest to consider the possible reasons for having obtained such a value. We conjecture the following two factors as responsible (in general) for relatively high k-values in LISE estimation: (1) mis-specifications in (of) the model, and (2) a large loss in degrees of freedom, relative to the size of the sample, when "fitting the denominator" of the least variance ratio, as compared to fitting the numerator.[6]

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[6] That is, linear combinations of the specified endogenous variables (in a particular structural equation) are regressed on only those predetermined variables specified (in a particular structural equation) in the "numerator"; but on all predetermined variables in the system in the "denominator" (so as to obtain the so-called least variance ratio). We are thus suggesting that the residual variance in the denominator may be substantially smaller than in the numerator simply because the number of predetermined variables in the system is large relative to the sample size.

Most likely, a combination of these factors is generally operative (as well as other factors we did not think of) and thus we cannot pinpoint the "problem" precisely (or separate individual effects). We do know, however, that high simple correlations between variables in this study were prevalent; and also that 8-10 fewer degrees of freedom, in a total sample size of 21, were applicable when the "denominator" was fitted.

2. Marketing in the Cattle-Beef Sector

This relation can be interpreted in terms of the direct effects of the specified variables on the price of beef cattle at the farm (PBEEFF). The coefficients based on 3SLS(2SLS) appear plausible and they are all statistically significant. A positive association between the farm and retail prices was expected, and the corresponding ε(PBEEFF/PBEEFR) = + .419.

When viewed as a derived demand for beef cattle, this relation indicates that increased levels of production for slaughter (QBEEFP) are associated with lower farm prices (PBEEFF), as expected. The 3SLS(2SLS) negative coefficient estimate for QBEEFP corresponds to an ε(PBEEFF/QBEEFP) = -1.755. (It is informative to compare this elasticity with the analogous statistic from equation 1, i.e., ε(PBEEFR/QBEEFC) = -1.043; the implication being that an equal percentage change in each of the respective quantities would have, <u>ceteris paribus</u>, a relatively greater (inversely associated) direct impact on the farm price).

A positive DISPY coefficient estimate was expected insofar as beef (and beef cattle) demand shifts have been positively correlated with real changes in consumers' purchasing power; and the estimated ε(PBEEFF/DISPY) = +1.734.

Again, for comparative purposes (from the reduced form PBEEFF equation), we calculated ε^T(PBEEFF/DISPY) = 4.090.

The negative CMKTGM coefficient and ε(PBEEFF/CMKTGM) =

Table 4.2

MARKETING IN THE CATTLE-BEEF SECTOR:
COEFFICIENT ESTIMATES AND RELATED STATISTICS

	PBEEFF	PBEEFR	QBEEFP	CONSTANT	DISPY	CMKTGM	K	R^2	D.W.
a) 3SLS(2SLS)	-1.0	.1100	-.00304	21.38	.1311	-.4043	n.a.	.9727	1.84
		.0336	.00038	2.24	.0171	.0846			
b) 2SLS	-1.0	.1091	-.00303	20.88	.1307	-.3803	1	.9729	1.86
		.0456	.00052	3.07	.0233	.1266			
c) UNK	-1.0	.0966	-.00320	21.30	.1381	-.3586	1.29	.9715	1.93
		.0468	.00054	3.15	.0239	.1298			
d) LISE	-1.0	.0181	-.00428	23.85	.1852	-.2190	2.35	.9513	1.95
		.0718	.00087	4.30	.0385	.1824			
e) OLS	-1.0	.1400	-.00261	19.84	.1126	-.4330	0	.9744	1.63
		.0402	.00045	2.90	.0201	.1191			
f) 3SLS(UNK)	-1.0	.1033	-.00313	21.53	.1351	-.3887	n.a.	.9720	1.88
		.0345	.00039	2.29	.0175	.0869			
g) 3SLS(LISE)	-1.0	.0800	-.00359	21.94	.1532	-.3127	n.a.	.9644	1.95
		.0436	.00049	2.87	.0220	.1101			
h) I3SLS	-1.0	.1751	-.00222	19.15	.0949	-.5087	n.a.	.9729	1.32
		.0258	.00028	1.80	.0127	.0542			

$-.493$ (and, also, ε^T(PBEEFF/CMKTGM) = $-.734$) indicate that changes in the real costs of marketing meat are inversely associated with changes in real farm beef cattle prices. This result seems plausible since the direct effect of higher marketing costs, given the retail price, would imply lower farm prices.

The 2SLS and UNK estimates are quite similar to the 3SLS (2SLS) estimates in this equation; OLS estimates are noticeably different but plausible. Two LISE coefficient estimates are not statistically significant and the PBEEFR coefficient estimate appears implausible.

3. Slaughter Supply of Beef Cattle at the Farm

In this supply equation, all of the 3SLS(2SLS) estimates of the coefficients are statistically significant. The negative PBEEFF coefficient and the corresponding ε(QBEEFP/PBEEFF) = $-.137$ are consistent with the hypothesis that the short run (in this case one year) impact of a price increase (decrease) is to increase (decrease) inventory levels, with a resulting short run <u>decrease</u> (increase) in slaughter supply.

Since, however, we do not regard a negative slaughter supply elasticity as plausible in a longer run situation (e.g., 3 to 5 years), we explore this aspect of the producer-segment behavioral relations of the model in greater detail later in this chapter. In light of that extension of the analysis, this fitted relation may be more adequately evaluated.

Table 4.3

SUPPLY OF BEEF CATTLE AT THE FARM: COEFFICIENT ESTIMATES AND RELATED STATISTICS

	QBEEFP	PBEEFF	CONSTANT	IBEEFF1	IBEEFNF1	PROTEIN	K	R^2	D.W.
a) 3SLS(2SLS)	-1.0	-79.286	5093.26	.6826	.1364	-32.27	n.a.	.9809	1.05
		24.074	1432.29	.1497	.0203	12.14			
b) 2SLS	-1.0	-92.08	7665.29	.4521	.1458	-55.19	1	.9839	1.40
		28.18	2084.33	.2046	.0275	18.26			
c) UNK	-1.0	-87.73	7551.18	.4517	.1460	-54.85	1.29	.9837	1.07
		28.35	2096.57	.2058	.0277	18.37			
d) LISE	-1.0	-54.24	6672.29	.4485	.1474	-52.20	3.10	.9805	1.27
		33.39	2316.29	.2251	.0303	20.12			
e) OLS	-1.0	-105.78	8024.64	.4534	.1452	-56.27	0	.9842	1.41
		26.86	2057.42	.2030	.0273	18.11			
f) 3SLS(UNK)	-1.0	-78.76	5096.75	.6821	.1364	-32.39	n.a.	.9809	1.05
		24.20	1429.93	.1497	.0203	12.10			
g) 3SLS(LISE)	-1.0	-66.52	5360.67	.6570	.1333	-35.82	n.a.	.9802	1.06
		24.48	1394.93	.1458	.0198	11.51			
h) I3SLS	-1.0	-65.67	-974.665	.7927	.1701	22.74	n.a.	.9636	.809
		34.47	1160.22	.1123	.0167	7.463			

All of the other coefficient estimates are as expected, and it seems particularly pertinent that the coefficient estimates of + .6826 and + .1364 for IBEEFF1 and IBEEFNF1, respectively, are substantially different and both statistically significant. (Note, however, the differences between the magnitudes of the IBEEFF1 coefficients for the alternative estimators.) The measures ε(QBEEFP/IBEEFF1) = + .322 and ε(QBEEFF/IBEEFNF1) = + .555, reflect the opposite relative importance of the two inventory components on current beef slaughter, however; and this is due to the average levels of these variables (the average IBEEFNF1 level was approximately 46,000,000 head, as compared to an average IBEEFF1 level of about 5,300,000 head over the sample period). The corresponding reduced form elasticity estimates, ε^T(QBEEFP/IBEEFF1) = .478, and ε^T(QBEEFP/IBEEFNF1) = .823, further support the distinction of the two inventory components.

Finally, the PPROTEIN estimated coefficient is negative as expected, which implies that increases in current "supplement" feed prices are associated with decreases in QBEEFP; and the ε(QBEEFP/PPROTEIN) = -.191 (also, the ε^T(QBEEFP/PPROTEIN) = -.283). Since feed costs are the major variable cost component in the production of beef cattle (protein supplements particularly in beef feeding operations), it seems reasonable that higher feed costs have important direct effects on current production. One caution with regard to this estimate is that over the sample period, high protein content feeds have become increasingly recognized (and used) as important to high quality "finishing" of beef animals. Thus, the demand has shifted and relatively higher levels of protein feeds have apparently been used despite the higher costs of these inputs.

The 3SLS(2SLS) coefficient estimates are again distinctly different from the single equation estimates; but compared among themselves the 2SLS, UNK, LISE and OLS coefficient estimates are quite similar (except for PBEEFF). The 3SLS(UNK and 3SLS(LISE) estimates (as is usually the case) are quite similar to the 3SLS(2SLS) results. The I3SLS estimates (again, these are converged estimates beginning with either 2SLS, UNK or LISE results), in this particular equation, are substantially different from the others (in particular note that the I3SLS results are even markedly different from the 3SLS(2SLS) estimates, which is atypical relative to a similar comparison of the other equation estimates).

4. Inventory Demand for Beef Cattle Retained for Feeding at the Farm

Total beef cattle production flows into either slaughter or inventory. The above slaughter supply equation, plus this equation and the following inventory relation were postulated to account for the main total beef cattle production components.

Table 4.4

INVENTORY DEMAND FOR BEEF CATTLE RETAINED FOR FEEDING AT THE FARM: COEFFICIENT ESTIMATES AND RELATED STATISTICS

	IBEEFF2	PBEEFF	POMEATF	CONSTANT	IBEEFF1	K	R^2	D.W.
a) 3SLS(2SLS)	-1.0	36.475	-49.330	731.67	.9669	n.a.	.9696	2.88
		17.390	30.498	850.52	.0599			
b) 2SLS	-1.0	42.635	-60.437	957.13	.9447	1	.9706	2.85
		21.161	37.917	1036.12	.0727			
c) UNK	-1.0	40.310	-52.330	770.31	.9571	1.33	.9700	2.85
		21.356	38.266	1045.66	.0734			
d) LISE	-1.0	7.681	92.960	-2740.17	1.1779	2.98	.9237	2.01
		37.516	92.073	2354.29	.1571			
e) OLS	-1.0	47.697	-76.080	1307.31	.9204	0	.9710	2.81
		19.933	32.223	903.69	.0659			
f) 3SLS(UNK)	-1.0	36.023	-47.655	690.41	.9699	n.a.	.9695	2.88
		17.632	30.719	857.54	.0605			
g) 3SLS(LISE)	-1.0	17.013	-28.043	312.69	1.0352	n.a.	.9639	2.83
		25.136	45.264	1278.53	.0893			
h) I3SLS	-1.0	38.811	-49.584	677.61	.9695	n.a.	.9697	2.88
		17.101	30.343	849.65	.0597			

These three components are considered as jointly related producer segment behavior variables, and the purpose of our approach is to account analytically for such interdependencies. The results for the inventory demand for beef cattle retained for feeding purposes equation are presented next.

The signs of the estimated coefficients in this relation are as expected (except for the POMEATF coefficient based on LISE). Two estimated coefficients, that of POMEATF and the CONSTANT, are generally not statistically significant, however.

The positive PBEEFF coefficient estimate indicates that increases in the level of ending inventory retained for feeding (IBEEFF2) are associated with increases in farm prices. It should be noted that PBEEFF was postulated to represent both the cost of feeders and an approximate expected product price (see the Economic Model section of Chapter III). When PBEEFF represents the former, then we would expect a negative association with IBEEFF2; and in contrast, a positive association was expected in the latter case. Assuming that the specification holds reasonably well, then the coefficient estimate obtained must be interpreted as a net result, i.e., on the average the net response to an increase in farm price is an increase in the ending inventory of beef cattle on feed. Based on the 3SLS (2SLS) procedure, an ε(IBEEFF2/PBEEFF) = + .013 was calculated, i.e., a one per cent increase in the farm price of beef cattle is associated with a .013 per cent direct increase in ending inventory on feed.

With regard to POMEATF, the negative coefficient estimate implies that there has been some competition for resources among competing farm enterprises; and ε(IBEEFF2/POMEATF) = - .181. Since the underlying coefficient estimate is not statistically significant, we do not place too much reliability on this particular derived elasticity estimate.

The beginning inventory (IBEEFF1) was postulated as one measure of current period production capability or previous period scale of operation and the coefficient estimates obtained indicate its importance; the corresponding ε(IBEEFF2/IBEEFF1) = + .922, and the reduced form ε^T(IBEEFF2/IBEEFF1) = + .886.

In actuality, the IBEEFF2 component of total inventory has been largely, if not almost entirely, composed of animals which were classified as IBEEFNF1 at the beginning of the period. Thus, it seemed reasonable to expect this variable (IBEEFNF1) to have had an effect on IBEEFF2. See Appendix A for an alternative specification which included IBEEFNF1 as a variable in this relation (fitted by 2SLS).

5. Inventory Demand for Beef Cattle Not Retained for Feeding at the Farm

In this relation, the second component of total ending inventory (IBEEFNF2) is the leading endogenous variable, and

Table 4.5

INVENTORY DEMAND FOR BEEF CATTLE NOT-RETAINED FOR FEEDING AT THE FARM: COEFFICIENT ESTIMATES AND RELATED STATISTICS

	IBEEFNF2	PBEEFF	CONSTANT	IBEEFNF1	ARANGECI	K	R^2	D.W.
a) 3SLS(2SLS)	-1.0	358.63	-12564.8	1.0263	77.66	n.a.	.9937	1.05
		67.72	3419.8	.0186	43.20			
b) 2SLS	-1.0	377.83	-11138.2	1.0239	56.11	1	.9937	1.07
		76.74	4171.6	.0209	53.45			
c) UNK	-1.0	374.35	-11155.1	1.0241	57.07	1.33	.9938	1.07
		76.77	4173.3	.0209	53.47			
d) LISE	-1.0	237.19	-11822.8	1.0323	94.91	6.87	.9922	1.00
		94.90	4659.6	.0235	60.71			
e) OLS	-1.0	387.01	-11093.4	1.0234	53.58	0	.9938	1.07
		73.18	4168.1	.0209	53.05			
f) 3SLS(UNK)	-1.0	358.34	-12766.7	1.0263	80.32	n.a.	.9937	1.05
		67.73	3418.3	.0186	43.16			
g) 3SLS(LISE)	-1.0	332.22	-11839.42	1.0330	71.10	n.a.	.9935	1.05
		72.14	3546.08	.0206	44.58			
h) I3SLS	-1.0	362.11	-10803.69	1.0260	54.56	n.a.	.9937	1.07
		63.68	2567.72	.0182	29.77			

we can interpret the estimates in terms of their direct effect on IBEEFNF2. The coefficient estimates for PBEEFF are positive and statistically significant. Based on 3SLS(2SLS) the corresponding ε(IBEEFNF2/PBEEFF) = + .147. As in the other inventory relation, the PBEEFF variable was postulated to represent both the cost of holding beef cattle and an expected product price. Thus, the PBEEFF coefficient estimate, and the corresponding elasticity estimate, refer to the net result of these two offsetting factors.

The beginning period non-fed inventory variable (IBEEFNF1) coefficient (+1.0263) indicates that absolute changes in IBEEFNF1 have, on the average, been associated with even larger absolute changes in IBEEFNF2. In relative terms, the ε(IBEEFNF2/IBEEFNF1) = +.989 in the structural relation (and ε^T(IBEEFNF2/IBEEFNF1) = + .702 based on the reduced form 3SLS(2SLS) coefficient estimate).

In this relation an average range condition index (ARANGECI) was specified to represent the carrying capacity of the principal range and grassland areas; and also, indirectly, the general availability of feedstuffs in the principal cow-calf breeding herd regions. An increase in the index value would imply improved range conditions and generally more roughage feedstuffs, so that one might expect a positive coefficient on the ARANGECI variable. In this fitted relation the estimated coefficient is positive and "almost" significant based on the 3SLS(2SLS) procedure, i.e., the ratio of the estimated coefficient to the estimated standard error is about 1.8.

Both the structural form and the reduced form corresponding elasticity estimates for IBEEFNF2 with respect to ARANGECI were estimated as + .128 (based on the 3SLS(2SLS) coefficient estimates). The reliability of these estimates is somewhat questionable, the high standard errors being perhaps partly due to the fact that average range conditions over the sample period were not dramatically different from "normal" for any sustained lengths of time.

6. Demand for Other Meat at Retail[7]

The estimated coefficients in this demand relation have their expected signs and they are all statistically significant for each of the estimation procedures. The LISE estimates are

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[7]The single equation results reported here for this equation (2SLS, UNK, LISE) were computed with NOMIMPORT not included in the set of predetermined variables in the system. (All 3SLS computations, however, included all the predetermined variables in the system.) The resulting single equation estimates have nearly the same asymptotic properties as would estimates computed with NOMIMPORT included (in particular, they are consistent, but presumably somewhat less efficient). The 2SLS estimates for this equation were recomputed with NOMIMPORT included (in the set of predetermined variables in the system), a similar recomputation was also done for a corresponding reason on equation 1, and the resulting 3SLS(2SLS) estimates for <u>all</u> equations were also obtained. These results are summarized in Appendix E. In all cases the actual numerical coefficients obtained differ only negligibly from those reported here.

Table 4.6

DEMAND FOR OTHER MEAT AT RETAIL:
COEFFICIENT ESTIMATES AND RELATED STATISTICS

	POMEATR	PBEEFR	QOMEATC	CONSTANT	DISPY	K	R^2	D.W.
a) 3SLS(2SLS)	-1.0	.6536	-.00843	82.86	.2577	n.a.	.8142	1.34
		.0686	.00135	9.02	.0511			
b) 2SLS	-1.0	.6419	-.00894	86.50	.2787	1	.8155	1.40
		.0872	.00172	11.38	.0650			
c) UNK	-1.0	.6726	-.00939	87.77	.2939	1.29	.8019	1.44
		.0903	.00178	11.79	.0673			
d) LISE	-1.0	.7798	-.01167	96.58	.3725	1.97	.6962	1.49
		.1256	.00247	15.19	.0920			
e) OLS	-1.0	.5657	-.00806	84.99	.2508	0	.8283	1.25
		.0749	.00134	9.18	.0511			
f) 3SLS(UNK)	-1.0	.6616	-.00858	83.39	.2625	n.a.	.8113	1.35
		.0704	.00139	9.28	.0525			
g) 3SLS(LISE)	-1.0	.6308	-.00848	85.23	.2583	n.a.	.8181	1.34
		.0890	.00173	11.43	.0650			
h) I3SLS	-1.0	.6558	-.00803	80.18	.2421	n.a.	.8129	1.29
		.0647	.00112	7.72	.0423			

larger absolutely than the alternative estimates. Again, the 3SLS(2SLS) estimates appear plausible and the primary discussion is based on those estimates.

The positive 3SLS(2SLS) PBEEFR coefficient estimate corresponds with an ε(POMEATR/PBEEFR) = + .804, which indicates the relative association between beef and other meat retail prices. (an interesting comparison is that ε(POMEATR/PBEEFR) = + .804 > (PBEEFR/POMEATR) = + .383; the latter estimate was calculated above in relation 1, i.e., demand for beef at retail).[8]

In this demand relation, a negative coefficient estimate for QOMEATC was obtained (as expected), and the corresponding ε(POMEATR/QOMEATC) = - 2.277. (Another comparison with the retail beef demand relation is that ε(PBEEFR/QBEEFC) = - 1.043. These results are commensurate with stating that the demand for beef is more "price elastic" than the demand for other meat at retail, i.e., based on considering the <u>reciprocals</u> of the above structural form elasticities of prices with respect to quantities as "price elasticities". A price elasticity is the common expression for an elasticity of consumption (quantity) with respect to the price of the good consumed.)

Finally, in this relation, the DISPY variable (which is also considered to reflect the effects of population) estimated

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[8] Similar findings have been reported elsewhere; see, for example: Riley, H. M.: <u>Some Measurements of Consumer Demand for Meats</u>, Ph.D. Thesis, Michigan State University, 1954.

coefficient is positive and statistically significant. The corresponding ε (POMEATR/DISPY) = + 1.102; and the ε^T(POMEATR/DISPY) = + 3.736. While both estimates are positive, the total effect of DISPY, as indicated by the reduced form estimate, is considerably larger than the direct effect of DISPY on POMEATR. (Continuing our comparisons with the retail beef demand equation, we note that ε (PBEEFR/DISPY) = + 1.230 and ε^T(PBEEFR/DISPY) = + .3.277.) The lower "R^2's" in this equation, relative to the other equations in general, should be noted. Apparently, important variables have not been included in this relation based on the "R^2's" as comparative indicators.

7. Marketing in the Other Livestock-Meat Sector

The normalizing variable in this relation was POMEATF, and this tends to place the main focus on interpreting this relation as a derived demand for other livestock. The signs for all estimated coefficients are as expected and statistically significant, except for LISE. The LISE estimates are particularly unreasonable in this relation. Based on the 3SLS(2SLS) coefficient estimates, then for POMEATR, a corresponding ε(POMEATF/POMEATR) = + 1.053. We regard this estimate as plausible, but in contrast we note that ε(PBEEFF/PBEEFR) = + .419 was derived above in the cattle-beef sector marketing-firm behavior equation.

The negative coefficient estimate for QOMEATP was ex-

Table 4.7

MARKETING IN THE OTHER LIVESTOCK-MEAT SECTOR:
COEFFICIENT ESTIMATES AND RELATED STATISTICS

	POMEATF	POMEATR	QOMEATP	CONSTANT	DISPY	CMKTGM	K	R^2	D.W.
a) 3SLS(2SLS)	-1.0	.3563	-.00130	24.00	.0364	-.5380	n.a.	.9572	1.60
		.0247	.00036	4.98	.0153	.1185			
b) 2SLS	-1.0	.3444	-.00120	24.24	.0324	-.5449	1	.9580	1.54
		.0290	.00044	6.23	.0188	.1556			
c) UNK	-1.0	.3426	-.00121	24.49	.0329	-.5474	1.29	.9579	1.53
		.0290	.00044	6.24	.0188	.1557			
d) LISE	-1.0	2.6212	-.17710	1901.59	7.4940	-42.6475	2.83	-773.6	2.01
		87.0304	6.71704	71690.65	284.9295	1607.8114			
e) OLS	-1.0	.3502	-.00116	23.44	.0308	-.5370	0	.9581	1.57
		.0282	.00037	5.62	.0157	.1442			
f) 3SLS(UNK)	-1.0	.3555	-.00131	24.07	.0368	-.5357	n.a.	.9571	1.60
		.0247	.00036	4.94	.0152	.1168			
g) 3SLS(LISE)	-1.0	-1.2625	-.06488	681.72	2.6120	-7.3532	n.a.	-.8812	1.63
		2.8832	.03098	442.58	1.2897	9.7868			
h) I3SLS	-1.0	.3474	-.00128	23.09	.0349	-.4737	n.a.	.9562	1.66
		.0242	.00033	4.53	.0136	.1057			

pected, insofar as this composite marketing-firm behavior relation reflects a derived demand at the farm. The corresponding 3SLS(2SLS) ε(POMEATF/QOMEATP) = - 1.060. (In comparison, the analogous estimate from the cattle-beef sector marketing relation is ε(PBEEFF/QBEEFP) = - 1.755).

With regard to the DISPY variable, the positive coefficient estimate implies that shifts in the derived demand for other livestock are positively correlated with consumers income (and, in part, other factors such as population or trend). An ε(POMEATF/DISPY) = + .460 was calculated (and this estimate is less than the analogous estimate for beef cattle, i.e., ε(PBEEFF/DISPY) = + 1.734; which seemed plausible given the apparent shift in beef-meat consumption relative to other meats). Also we note the reduced form estimate ε^T(POMEATF/DISPY) = 4.392.

Turning to the cost of marketing meat per pound (CMKTGM) variable, the negative estimated coefficient (and both the structural and reduced form elasticity estimates, i.e., ε(POMEATF/CMKTGM) = - .625 and ε^T(POMEATF/CMKTGM) = - .751) indicate negative effects of increases in CMKTGM on POMEATF. In the structural equation, we expected a negative coefficient estimate, *ceteris paribus*, i.e., given especially the price of other meat at retail.

8. Supply of Other Livestock at the Farm

The coefficient estimates have their expected signs and are statistically significant in this supply response relation. Note that the OLS procedure is theoretically applicable, and also that the 2SLS, UNK, and LISE procedures would yield identical single equation estimates. The 3SLS procedure yields different estimates because additional "information" from the estimated disturbance covariance matrix is utilized. The R^2 in the OLS fit indicates that .9732 percent of the variation of the endogenous (dependent) variable (QOMEATP) is explained by the included variables.

Based on the 3SLS(2SLS) estimator, the POMEATFL coefficient estimate of +244.89 indicates that current output is directly associated with changes in previous period prices of other livestock, as expected. The corresponding ε (QOMEATP/POMEATFL) = + .284, which indicates a relatively inelastic supply response function in the short run. This estimate supports the generally held belief that such farm supply relations are inelastic with respect to price in the short run (1 year in this case). One might note that this elasticity represents both the "direct" and the "total" effects of POMEATFL on QOMEATP since the structural form and the reduced form relations are the same.

As expected, the lagged feed grains price index is found

Table 4.8

SUPPLY OF OTHER LIVESTOCK AT THE FARM:
COEFFICIENT ESTIMATES AND RELATED STATISTICS

	QOMEATP	CONSTANT	POMEATFL	PFEEDIDL	QOMEATPL	K	R^2	D.W.
a) 3SLS(2SLS)	-1.0	9933.1	224.89	-96.28	.8083	n.a.	.9721	2.89
		1810.1	51.85	15.94	.0451			
b) OLS	-1.0	8378.9	187.97	-79.15	.8308	0	.9732	2.86
		2267.6	67.60	20.99	.0539			
c) 3SLS(UNK)	-1.0	9963.7	224.67	-96.35	.8072	n.a.	.9721	2.89
		1790.0	51.48	15.73	.0449			
d) 3SLS(LISE)	-1.0	9849.3	191.60	-88.15	.7992	n.a.	.9725	2.87
		1691.1	47.02	13.92	.0437			
e) I3SLS	-1.0	13237.9	246.35	-120.57	.7487	n.a.	.9651	2.73
		1815.7	50.68	15.36	.0481			

to be inversely associated with QOMEATP in the current period. Based on the coefficient estimate obtained from the 3SLS(2SLS) procedure, the ε(QOMEATP/PFEEDIDL) = - .662.

The current level of production of other livestock for slaughter (QOMEATP) is found to be directly related to recent past behavior of producers. The positive coefficient estimate of QOMEATPL corresponds to an ε(QOMEATP/QOMEATPL) = + .784.

When this supply equation was specified in the Economic Model section of Chapter III, it was postulated as having been derived from a more basic theoretical relation, i.e.,

$$Q_t = a + bP_t^{1*} + cP_t^{2*} \qquad \text{(i')}$$

where $$P_t^{i*} = \gamma P_{t-1}^{i} + (1 - \gamma) P_{t-1}^{i*} \quad (i = 1,2) \qquad \text{(ii')}$$

and where the P_t^{i*} were defined as expected product and input prices. Further, it was noted that estimates of a, b, c, and γ could be derived from the structural equations coefficient estimates.

Let Q_t = QOMEATP, P_t^{1*} = the expected price of other livestock at the farm, and P_t^{2*} = expected price of feed grains, then the estimates of a, b, c, and γ are as follows:

$\hat{a}$ = 51815.

$\hat{b}$ = 1173.

$\hat{c}$ = -502. and

γ = .1917

The corresponding elasticities of QOMEATP with respect to the P_t^{i*}, calculated at the mean values of the actual POMEATF and PFEEDID variables[9] are: ε(QOMEATP/POMEATF*) = +1.4352, and ε(QOMEATP/PFEEDID*) = -3.3825. The long run supply elasticity estimates are approximately five times as large in magnitude as the short run (1-year) estimates.

Summary of Statistical Tests for the Identifiability of the Structural Relations

In this particular model, all of the behavioral relations, i.e., relations 1,..., 8, were "overidentified", a priori, based on the necessary order condition that $(g-1) < (K-k)$. That is, in each relation the number of predetermined variables outside the relation but in the system (K-k) was greater than the number of endogenous variables in the relation less one (g-1). The validity of the a priori exclusion of predetermined variables is subject to uncertainty, and alternative procedures have been developed to test for the identifiability of a structural relation.

In the following table (Table 4.9) the results of a test developed by Hood and Koopmans[10] for the LISE estimator are summarized. The test statistic $T \log_e (\hat{\ell}_1 \dot{\hat{\ell}}_2)$ has an asymptotic

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[9]For the 1936-41, 1949-63 sample period, the mean level of POMEATF was 20.46 (dollars per cwt.) and the mean level of PFEEDID was 112.65 (1957-59 = 100).

[10]Hood, W. C. and Koopmans, T. C.: Studies in Econometric Method, New York: John Wiley and Sons, Cowles Commission Monograph No. 14, 1953, Chap. VI, pp. 183-84.

Table 4.9

SUMMARY OF A TEST FOR THE IDENTIFIABILITY OF THE STRUCTURAL RELATIONS (HOOD AND KOOPMANS PROCEDURE)

Relation	Test statistic: $T\log_e (\ell_1 \ell_2)$	Degrees of freedom	Critical value $\chi^2 95$	Conclusion: identified or not identified
1	62.12	8	15.51	Identified
2	68.13	8	15.51	"
3	104.40	8	15.51	"
4	61.44	9	16.92	"
5	94.59	9	16.92	"
6	39.16	8	15.51	"
7	53.75	8	15.51	"
8	n.a.	-	-	-

Chi-square distribution with (K-k) - g + 2 degrees of freedom, such that if the test statistic is greater than or equal to the corresponding critical value one can conclude that the structural relation in question is identified.[11] In every case it is concluded that the structural relation is identified at the .05 significance level. One should note that the test is based on an asymptotic distribution, and experimental results suggest that this distribution may not be well approximated in finite sample sizes.[12] Some reservation is therefore placed on the

[11]See, Ibid., p. 183, for a more complete statement of the hypothesis being tested, and the authors comments that this test is actually a....."test of nonidentifiability rather than of identifiability."

[12]See, Johnston, J.: Econometric Methods, New York: McGraw-Hill, 1963, pp. 263-64; and Basmann, R. L.: "On Finite Sample Distributions of Generalized Classical Linear Identifiability Test Statistics," Journal of the American Statistical Association, Vol. 55, 1960.

reliability of these results.

Basmann has proposed an alternative test for the identifiability of structural relations which he considers to be more suited for typically small sample sizes. The test statistic is defined as a function of the least variance ratio (which corresponds to $\hat{\ell}_1$ in the above test and also to the reported k-value for the LISE procedure); namely, the test statistic is $\frac{T - K}{(K-k)-g+1} \hat{\phi}$, where $\hat{\phi}$ is $\hat{\ell}_1$ minus one $(\hat{\ell}_1-1)$. Basmann shows that this statistic has an $F_\alpha[(K-k)-g+1, T-K]$ distribution such that for

$$\frac{T - K}{(K-k)-g+1} \hat{\phi} \geq F_\alpha \; [(K-k)-g+1, T-K]$$

we would reject the null hypothesis that the "excluded" predetermined variable coefficients were zero, i.e., $H_0:\beta_2 = 0$, where β_2 denotes that set of coefficients.

The results of the Bassmann test for the identifiability of structural relations in this model are summarized in Table 4.10 (for the LISE estimator). In this case, for relation 5, the test statistic (5.28) is greater than the corresponding F-critical value (3.14) so the null hypothesis $(H_0:\beta_2 = 0)$ is rejected. All of the other relations are "identified" based on this test.[13] Since the LISE estimator tended to yield questionalbe parameter estimates in our model in general (relative

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[13] We note that this test is not a strict identifiability test, but rather a test of whether the excluded variable coefficients can be considered equal to zero (versus non zero).

Table 4.10

SUMMARY OF A TEST FOR THE IDENTIFIABILITY
OF THE STRUCTURAL RELATIONS (BASMANN PROCEDURE)

Relation	$\hat{\phi}$	Test statistic: $\frac{T-K}{(K-k)-g+1}\hat{\phi}$	Critical value: $F_{.05}[(K-k)-g+1, T-K]$	Conclusion: reject $H_0:\beta_2=0$ not reject
1	2.69	2.99	3.02	not reject
2	1.35	1.35	3.18	"
3	2.10	2.10	3.18	"
4	1.98	1.78	3.14	"
5	5.87	5.28	3.14	reject
6	.97	1.08	3.02	not reject
7	1.83	1.83	3.18	"
8	n.a.	-	-	-

to the alternative estimators), the results of these tests should probably not be regarded as conclusive.

Long Run Beef Supply

In this section we explore the "long run slaughter beef supply" implications of the estimated model. That is, what would be the long run response of the producer segment of the model to specified changes in prices of its products (beef and other meat), with "other things" held constant? The producer segment consists of four equations (no.'s 3,4,5 and 8) with six endogenous variables (QBEEFP, IBEEFF2, IBEEFNF2, QOMEATP, POMEATF and PBEEFF). For the purpose of this analysis, two of the six, namely, the two whose effects we are exploring, are treated as predetermined (in effect, specified or "controlled" by the investigator). The remaining four endogenous variables continue to be treated as endogenous; indeed, it is precisely the effects <u>on</u> the remaining endogenous variables (in particular; the effect on the supply of slaughter beef) <u>of</u> changes in the "controlled" variables, <u>through</u> the workings of the producer segment structural equations, which we wish to explore.

We have, thus, four structural producer-behavior equations, with four endogenous variables, two "controlled" variables and eight predetermined variables. More specifically the predetermined variables consist of both lagged endogenous variables (IBEEFF2, IBEEFNF1 and QOMEATPL) and exogenous variables (CONSTANT, POMEATFL, PPROTEIN, ARANGECI and PFEEDIDL). (Actually this analysis is relevant only because lagged endogenous variables are present in the producer segment structural equations.) The procedure will be to specify certain initial values for the lagged endogenous variables, certain fixed values for the exogenous variables and a certain set of alternative values for the controlled variables, allowing each choice of the latter values to prevail over some specified number of years or "time horizon", and then to compute the resulting values of the endogenous variables (in particular the supply of slaughter beef) that would be generated by the four structural equations. Further, the lagged endogenous variables (for each period after the first one) take on the computed values of their corresponding endogenous variables from the immediately preceding period (in effect, this allows the endogenous variables to change, in a manner conditioned by the fitted producer-segment structural equations, over the time horizon considered).

Computationally, this procedure is readily done by rewriting the four equations in "reduced form" with the four endogenous variables as dependent and including the two controlled variables on the right side as predetermined. For expository purposes this reduced form can be written as follows, with the endogenous variables predetermined variables and the estimated reduced form coefficient matrix partitioned as indicated:

$$\underset{(4 \times 1)}{\begin{bmatrix} \text{QBEEFP} \\ \text{IBEEFF2} \\ \text{IBEEFNF2} \\ \text{QOMEATP} \end{bmatrix}} = \underset{(4 \times 3)}{\hat{\pi}_1} \underset{(3 \times 1)}{\begin{bmatrix} \text{IBEEFF1} \\ \text{IBEEFNF1} \\ \text{QOMEATPL} \end{bmatrix}} + \underset{(4 \times 5)}{\hat{\pi}_2} \underset{(5 \times 1)}{\begin{bmatrix} \text{CONSTANT} \\ \text{POMEATFL} \\ \text{PPROTEIN} \\ \text{ARANGECI} \\ \text{PFEEDIDL} \end{bmatrix}} + \underset{(4 \times 2)}{\hat{\pi}_3} \underset{(2 \times 1)}{\begin{bmatrix} \text{POMEATF} \\ \text{PBEEFF} \end{bmatrix}}$$

or, for convenient reference, as

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \hat{\pi}_1 X_1 + \hat{\pi}_2 X_2 + \hat{\pi}_3 X_3$$

As initial values for X_1 (lagged endogenous) variables we specified their means (for the 1936-41, 1949-63 sample period); the fixed values for the X_2 (exogenous) variables were also set at their mean levels; and for the X_3 ("controlled") variables, POMEATF was set at its mean and PBEEFF was initially set at \$13.00/cwt.. In the meanner described above Y_1 and Y_2 were estimated for 50 periods. This procedure was repeated, changing only PBEEFF by $.25/cwt. increments (e.g., $13.25, 13.50, 13.75, ...), until PBEEFF was equal to $30.50/cwt.. The estimates of particular interest in this section are Y_1 (QBEEFP) and the corresponding "controlled" values of PBEEFF for each time horizon, which together provide our estimates of long run slaughter beef supply response for 50 different yearly time horizons.

With these estimates we were able to calculate slaughter beef supply price elasticities for any of the different length of run horizons and for any selected PBEEFF within the range of PBEEFF values indicated. A natural choice for a particular PBEEFF is its mean for the sample period, since all other X_1, X_2, and POMEATF variables were specified (only initially, however, for X_1) at their means. Some of the elasticities so calculated[14] are - .1381 for the 1-year horizon (which compares with the 3SLS(2SLS) structural equation estimate of -.137), +.1127 for the 3-year horizon and +.3284 for the 5-year horizon. Additional results are presented in Table 4.11.

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[14] For example, the 3-year horizon estimate was calculated as the inverse of the ratio of a percentage change in PBEEFF (namely, $19.75 - 19.25 = .50 divided by $19.50 which equals an .02564 percent change) to a corresponding percentage change in QBEEFP (namely, 12133 - 12098 = 35 divided by 12116 which equals an .002889 percent change): The ratio (.002889/.02564) = .1127 is our estimate of the point elasticity for PBEEFF = $19.50 and QBEEFC = 12116.

These results are consistent with a priori expectations regarding the nature of long run supply relations.

The purpose of considering the long run slaughter beef supply for such an extended time horizon and for such a wide range of farm beef prices (PBEEFF) was to investigate other attributes of slaughter beef supply through the workings of the producer-segment structural equations; such as, does the series of long run slaughter supply functions (as derived herein) converge to an "equilibrium" long run function; and is there an "equilibrium" PBEEFF through which each of the derived supply relations passes. On the first question, it turns out that there is not a long run supply curve short of an infinitely elastic supply function[15] (which we consider a possible weakness of the underlying producer-segment fitted structural equations). One possible explanation, since "trend" terms were not

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[15] To see that this statement is true (and to explicitly show why the long run supply function did not converge) we recognized first that once we specified POMEATF as a constant (at its mean level in the above procedure), then the producer-segment other livestock supply equation had none other than a constant (fixed) effect on the beef cattle producer-segment equations. (In essence, an equivalent analysis is a study of only the beef cattle producer-segment structural equations.) Second, while holding PBEEFF at a specified level, each of the inventory equations reduces to a simple first order difference equation of the form:

$$Y_t = \alpha Y_{t-1} + C \quad \text{(where C is constant)}.$$

The solution of this equation, starting with some initial value Y_0 is:

$$Y_t = \alpha^t Y_0 + (1 + \alpha + \alpha^2 + \ldots + \alpha^{t-1})C$$

Or equivalently [since $(1 + \alpha + \alpha^2 + \ldots + \alpha^{t-1}) = \frac{1 - \alpha^t}{1 - \alpha}$],

$$Y_y = \alpha^t Y_0 + \frac{1 - \alpha^t}{1 - \alpha} C$$

(Note that the solution is convergent if $\alpha < 1$, divergent if $\alpha > 1$.)

In particular, let Y_{1t} = QBEEFP, Y_{2t} = IBEEFF2, Y_{3t} = IBEEFNF2, $\alpha = .9669$ and $\beta = 1.0263$, (where the values of α and β are the 3SLS(2SLS) estimated lagged inventory coefficients in Equations (4) and (5) respectively); then, using the 3SLS(2SLS) estimates, we obtain:

From equation (4)

$$Y_{2t} = \alpha^t Y_{20} + \frac{1 - \alpha^t}{1 - \alpha} (731.67 - 49.330 \text{ POMEATF} + 36.475 \text{ PBEEFF})$$

From equation (5)

$$Y_{3t} = \beta^t Y_{30} + \frac{1 - \beta^t}{1 - \beta} (-12564.8 + 77.66 \text{ ARANGECI} + 358.63 \text{ PBEEFF})$$

From equation (3), substituting $Y_{2,t-1}$ and $Y_{3,t-1}$ from (4) and (5):

$$\begin{aligned} Y_{1t} = {} & 5093.26 \\ & + .6826\ \alpha^t Y_{20} + .6826 \frac{1 - \alpha^t}{1 - \alpha} (731.67 - 49.330 \text{ POMEATF} + 36.475 \text{ PBEEFF}) \\ & + .1364\ \beta^t Y_{30} + .1364 \frac{1 - \beta^t}{1 - \beta} (-12564.8 + 77.66 \text{ ARANGECI} + 358.63 \text{ PBEEFF}) \\ & - 32.27 \text{ PPROTEIN} - 79.286 \text{ PBEEFF} \end{aligned}$$

which may be rewritten as:

$$\begin{aligned} Y_{1t} = {} & 5093.26 - 32.27 \text{ PPROTEIN} \\ & + \alpha^t (.6826\ Y_{20}) + \beta^t (.1364\ Y_{30}) \end{aligned}$$

$$+ \frac{1 - \alpha^t}{1 - \alpha} (.6826)(731.67 - 49.330 \text{ POMEATF})$$

$$+ \frac{1 - \beta^t}{1 - \beta} (.1364)(-12564.8 + 77.66 \text{ ARANGECI})$$

$$+ \left[(.6826)(36.475) \frac{1 - \alpha^t}{1 - \alpha} + (.1364)(358.63) \frac{1 - \beta^t}{1 - \beta} \right.$$

$$\left. -79.286 \text{ PBEEFF} \right]$$

Putting in specified values for Y_{20} and Y_{30}, POMEATF and ARANGECI, and designating the various numerical constants by Ci's for simplicity, we obtain the following general form:

$$Y_{1t} = C_0 + c_1 \alpha^t + C_2 \beta^t$$

$$+ C_3(1 + \alpha + \ldots + \alpha^{t-1})$$

$$+ C_4(1 + \beta + \ldots + \beta^{t-1})$$

$$+ [C_5(1 + \alpha + \ldots + \alpha^{t-1}) + C_6(1 + \beta + \ldots + \beta^{t-1}) C_7] \text{ PBEEFF}$$

Now consider the difference:

$$Y_{1,t+1} - Y_{1t} = C_1 (\alpha^{t+1} - \alpha^t) + C_2(\beta^{t+1} - \beta^t)$$

$$+ C_3 \alpha^t + C_4 \beta^t$$

$$+ [C_5 \alpha^t + C_6 \beta^t] \text{ PBEEFF}$$

Hence, in general, if $\alpha, \beta < 1$, then $Y_{1,t+1} - Y_t$ for a given PBEEFF would converge; but since the estimated $\alpha = .9669$ and $\beta = 1.0263 > 1$ the difference diverges.

It was thought that a possible reason for the estimated β being greater than one might have been that the estimate had partly captured a purely trend effect. However, when this possibility was checked by re-estimating equation 5 including a separate trend term, the result was to increase, rather than decrease, the estimated β (see Appendix A).

specified in the structural equations, is that average trend effects over the sample period are included in our long run supply estimates (but see comment at end of footnote 15). On the second question, an approximate "equilibrium" PBEEFF was found within a small range of $13.80/cwt.. Another set of slaughter beef supply price elasticity estimates were calculated for PBEEFF centered on $13.75/cwt. (selected estimates are also presented in Table 4.11) and Figure 4.1 illustrates the slaughter beef supply function estimates for selected length of run horizons. Our main interest is in the pattern of elasticity estimates obtained rather than in attempting to draw any conclusions about the validity of any particular function for a possible specific usage; we do consider that this exploration does on the whole strengthen the plausibility of our fitted producer-segment structural equations.

Recently a colleague, Michel Petit,[16] reported beef production (including production for inventories) price elasticity estimates of + .12 for a one-year adjustment period, + .32 for the second year, and + .34 for the third year. His approach was basically a recursive model formulation culminating in a beef production variable as a function of the (estimated) quantities of feed-grains fed to beef cattle, of high-protein

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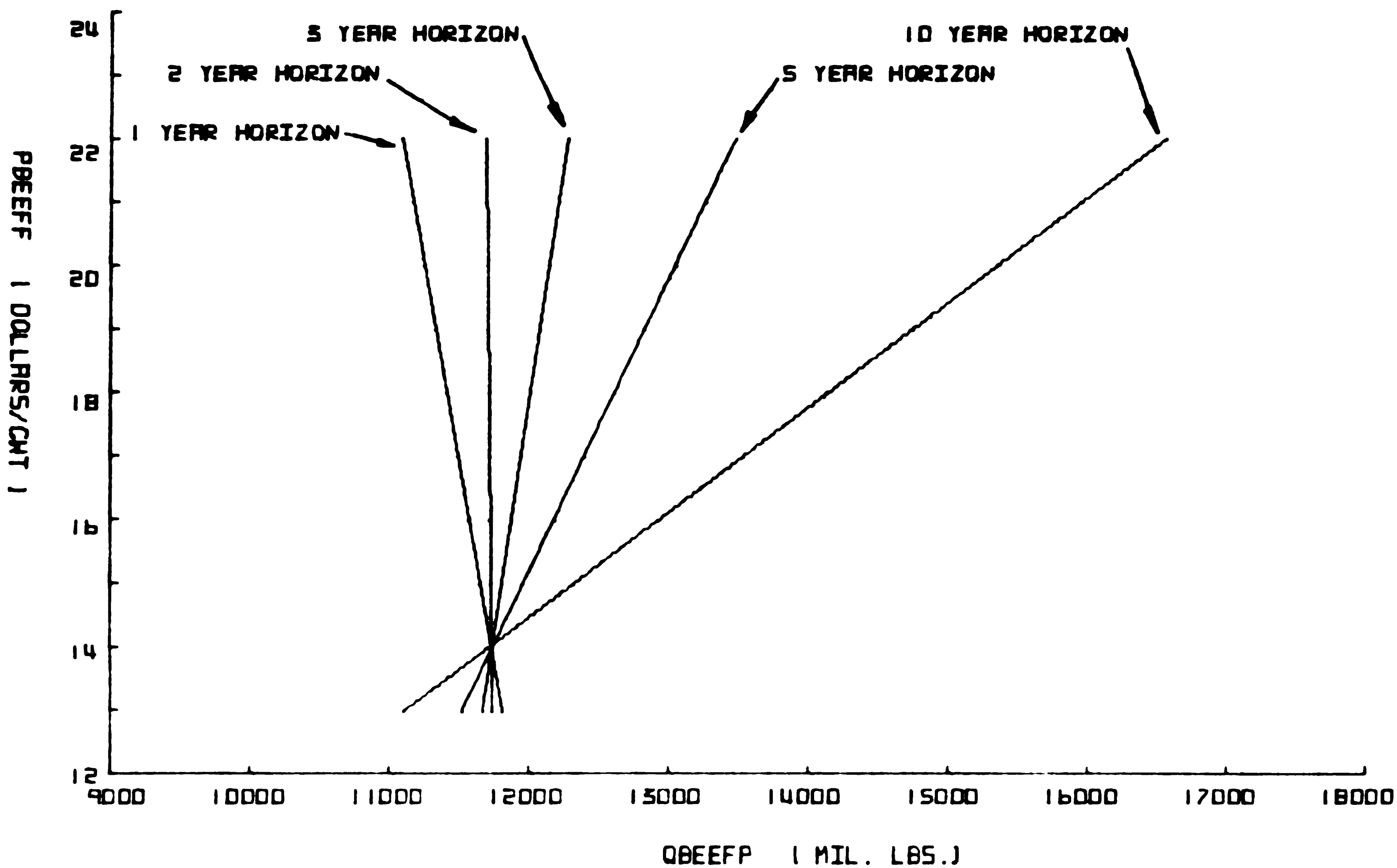
[16] Petit, M. J.: <u>Econometric Analysis of the Feed-Grain Livestock Economy</u>, Ph.D. Thesis, Michigan State University, 1964, pp. 174-181.

Table 4.11

LONG-RUN BEEF SUPPLY FUNCTIONS:
GENERATED DATA AND ESTIMATED SLAUGHTER SUPPLY PRICE ELASTICITIES

PBEEFF $1/cwt.	- QBEEFP (mil. lbs.) - 1 Year Horizon	2 Year Horizon	3 Year Horizon	5 Year Horizon	10 Year Horizon	20 Year Horizon
18.75	11350	11707	12604	12780	14593	18444
19.00	11330	11705	12081	12835	14745	18810
19.25	11310	11704	12098	12890	14896	19176
19.50	11290	11703	12116	12944	15048	19541
19.75	11270	11701	12133	12999	15200	19907
20.00	11250	11700	12150	13054	15351	20272
20.25	11231	11699	12167	13109	15503	20638
Estimated Supply Price Elasticity (at $19.50)	-.1381	-.0100	.1127	.3284	.7878	1.4619
13.25	11786	11737	11686	11576	11255	10402
13.50	11766	11736	11703	11631	11407	10768
13.75	11746	11734	11720	11685	11559	11134
14.00	11726	11733	11737	11740	11711	11499
14.25	11706	11731	11754	11795	11862	11865
14.50	11686	11730	11772	11849	12014	12230
Estimated Supply Price Elasticity (at $13.75)	-.1373	-.009549	.08115	.2625	.7255	1.888

FIGURE 4.1 ESTIMATED LONG-RUN SLAUGHTER BEEF SUPPLY



feeds fed to beef cattle, of labor used in beef production, and the number of non-dairy cattle on farms at the beginning of the year. His model included expected price of beef-cattle variables rather than actual prices, as predetermined in estimating the levels of inputs to be used during the current period. Thus, his price elasticity estimates are based on the recursive impact of expected prices on the various input components of the production relation. Nonetheless, his results are comparable, relatively, when considering various adjustment horizons. Further, his analysis indicated increased inventories given higher expected prices for beef, which implies that the one-year elasticity of beef-meat production alone would be lower than + .12. His results are therefore generally consistent with the results of this study.

Further Evaluation of the Fitted Structural Model

Another way of appraising the structural model estimated relationships is to observe how well the structures obtained explained the normalizing endogenous variables over the sample period. That is, consider each fited structural equation,

$$\hat{y}_{g*}(t) = \sum_{g \neq g*} \hat{\alpha}_{ig} \; y_g(t) + \sum_{k} \hat{\beta}_{ik} \; x_k(t)$$

as if all of the unexplained residuals, $\hat{u}_i(t)$, were in fact random errors in estimating y_{g*}. In other words, assume $\hat{\alpha}_{ig} = \alpha_{ig}$, $\hat{\beta}_{ik} = \beta_{ik}$ (and no errors in observing either the y's or x's), then $\hat{u}_i(t) = y_{g*}(t) - \hat{y}_{g*}(t)$. When viewed in this manner, the reported "R^2's" are indeed an indication of the relative amount of the variation of the normalizing variables (y_{g*}) which has been explained by the respective fitted structural equations.[17] This type of evaluation has an intuitive appeal since we tend to interpret the estimated structural equations in terms of the effects of the specified variables solely on the normalizing endogenous variable.

The following series of figures (Figures 4.2 to 4.9) graphically portray the estimated versus the actual series of the normalizing endogenous variables over the sample period (estimated series based on 3SLS(2SLS) parameter estimates). We also plot estimates for 1964 as an indication of how the parameter estimates "explain" the actual endogenous variables for 1964 (which are observations that were not included in our sample period). For greater facility in observing the nature of the residuals (in the manner described) we also plot the residuals as plus or minus deviations from the actual series.

---

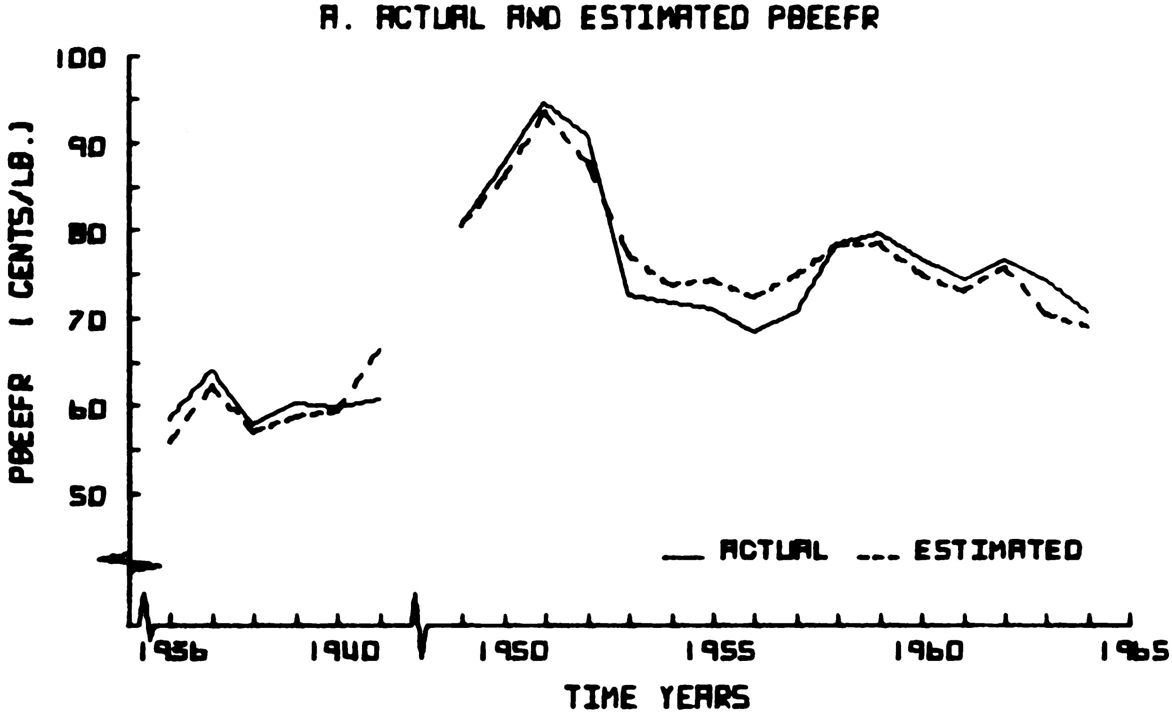
[17]Alternatively, we might wish to evaluate the residuals of our estimated linear combination of the endogenous variables in terms of a simultaneous coefficient of determination (provided such a statistic could be calculated - for developments along this line see, for example: Hooper, J. W.: "Simultaneous Equations and Canonical Correlation Theory," Econometrica, Vol. 27, 1959, pp. 245-256; and Theil, H: Economic Forecasts and Policy Amsterdam: North-Holland, 1961, p. 348.

An advantage of graphing the estimated and the actual series of the normalizing endogenous variables is that we can further note how well the mechanisms explain turning-points in the actual series. If there systematic deviations between the estimated and the actual series, then possibly that characteristic would be indicative that a correct specification of the equation (and/or model) had not been achieved.

We note, in general, that the figures reflect a reasonably close fit (which is implicit in the "R^2" statistic) between the estimated and actual series of the normalizing variables for each of the structural equations, with the exception of equation 6 (Figure 4.7: Demand for Other Meat at Retail, where the "R^2" = .81). While the figures are "self-explanatory", we briefly note in particular the following characteristics, equation by equation.

<u>Demand for Beef at Retail (Figure 4.2)</u>. The calculated R^2 was .93 (when considering PBEEFR as if it was the sole dependent variable). Except for 1955, the estimated PBEEFR moved in the same direction as the actual (observed) series. The larger residuals were for 1941, 1955-57, and 1963. Also, the pattern of the residuals appears somewhat cyclical over the sample period, so one might suspect that some other variable(s) should have been specified in this demand relation. Overall, the specified relation captured fairly well the direction of

FIGURE 4.2 STRUCTURAL EQUATION 1. DEMAND FOR BEEF AT RETAIL



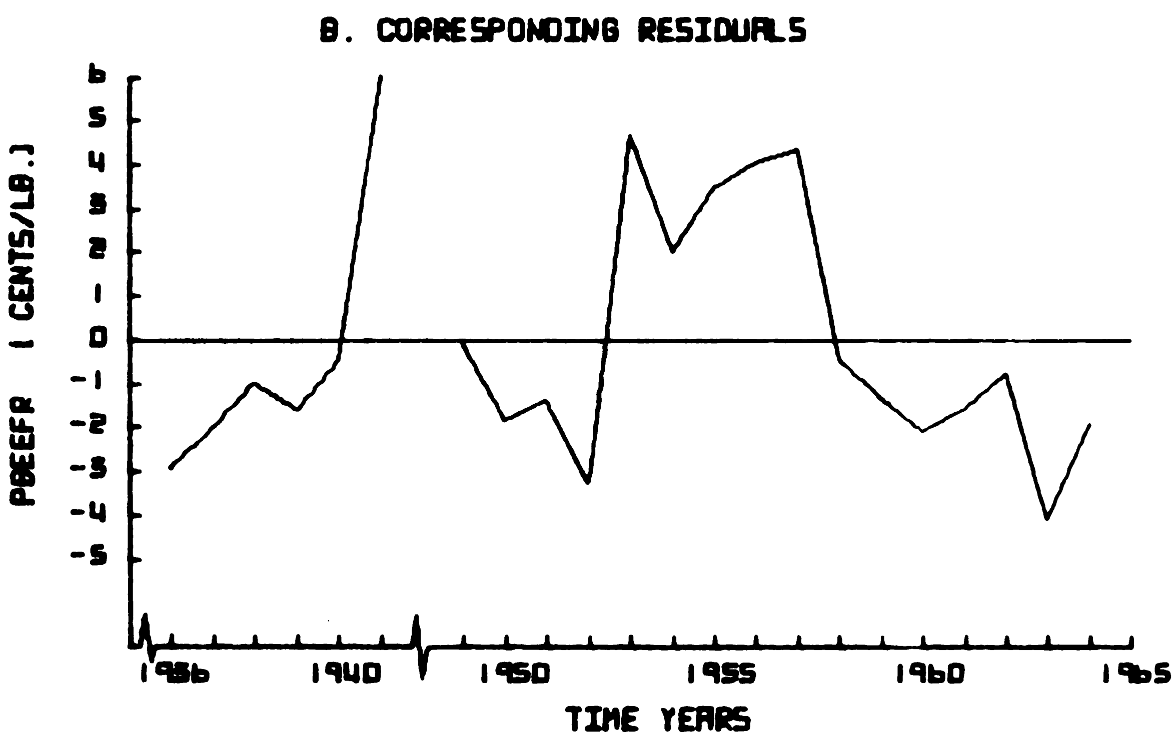
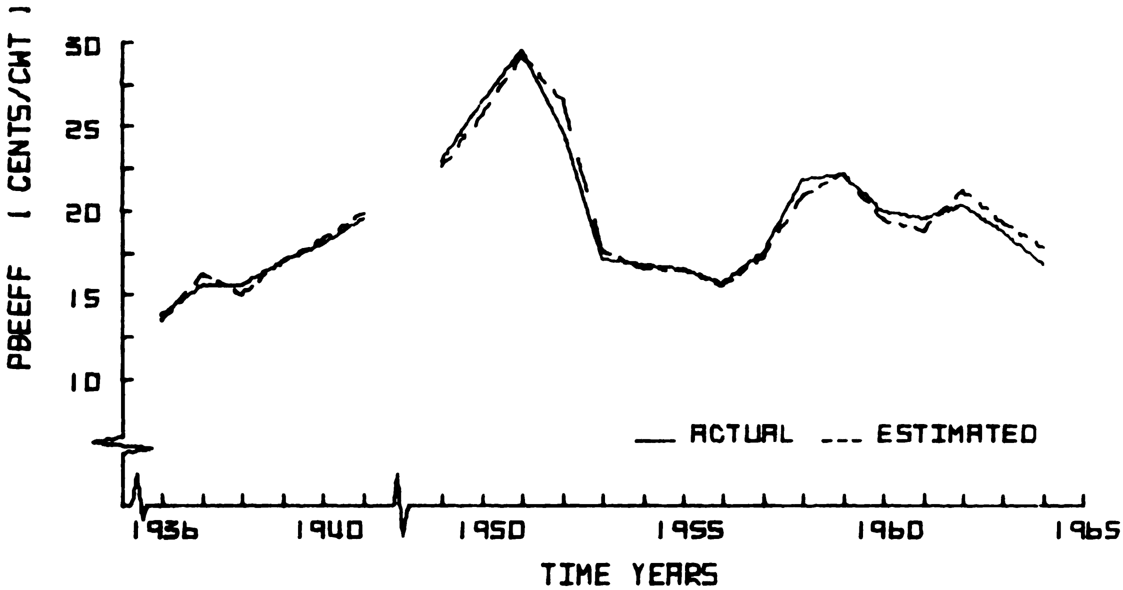


FIGURE 4.3 STRUCTURAL EQUATION 2. MARKETING IN THE CATTLE-BEEF SECTOR

A. ACTUAL AND ESTIMATED PBEEFF



B. CORRESPONDING RESIDUALS

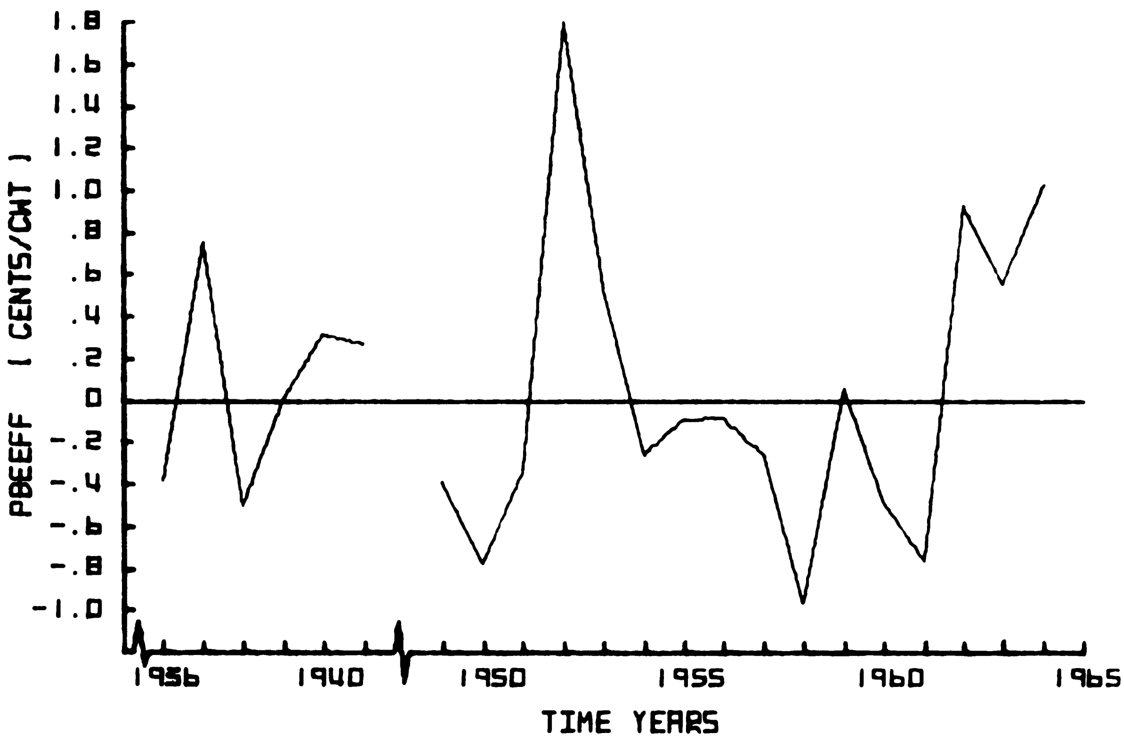


FIGURE 4.3 STRUCTURAL EQUATION 2. MARKETING IN THE CATTLE-BEEF SECTOR

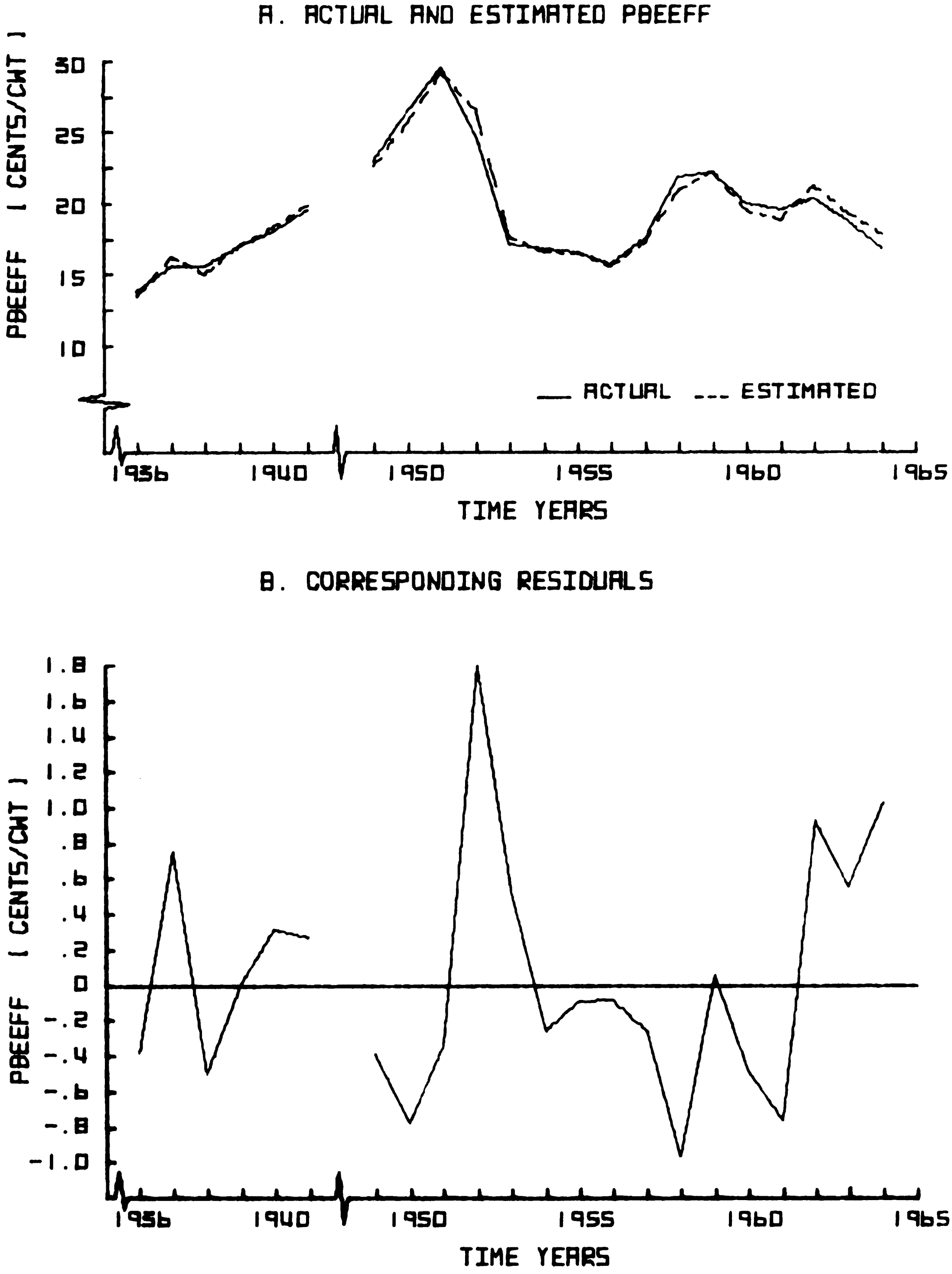
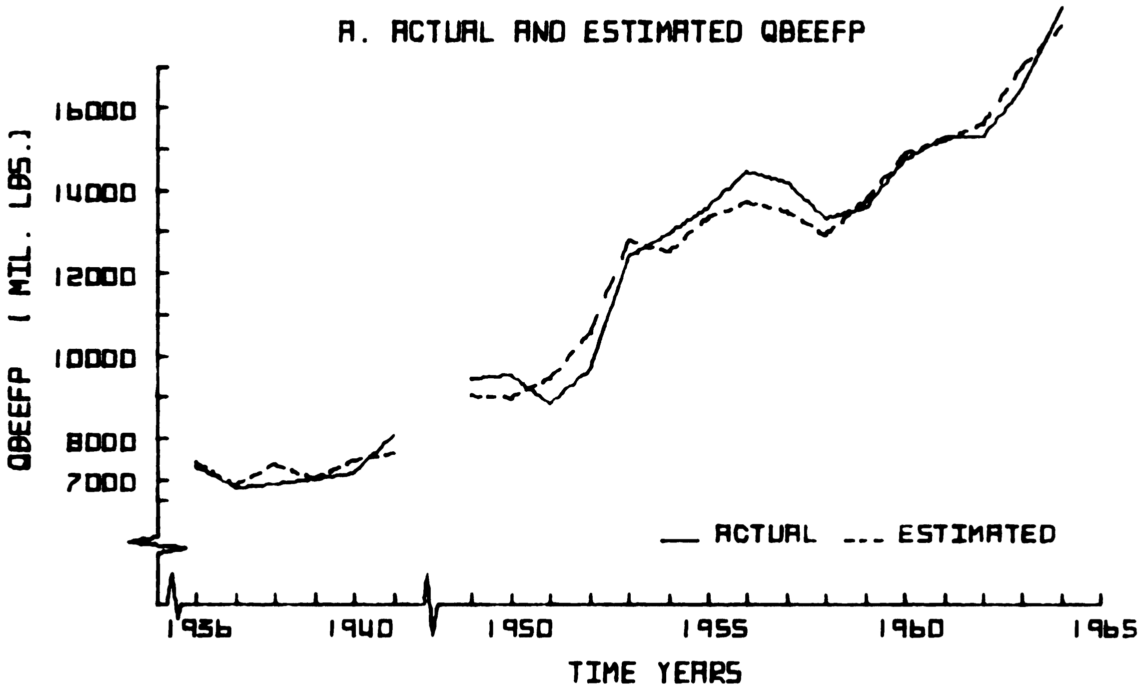


FIGURE 4.4 STRUCTURAL EQUATION 3. SLAUGHTER SUPPLY OF BEEF CATTLE AT THE FARM



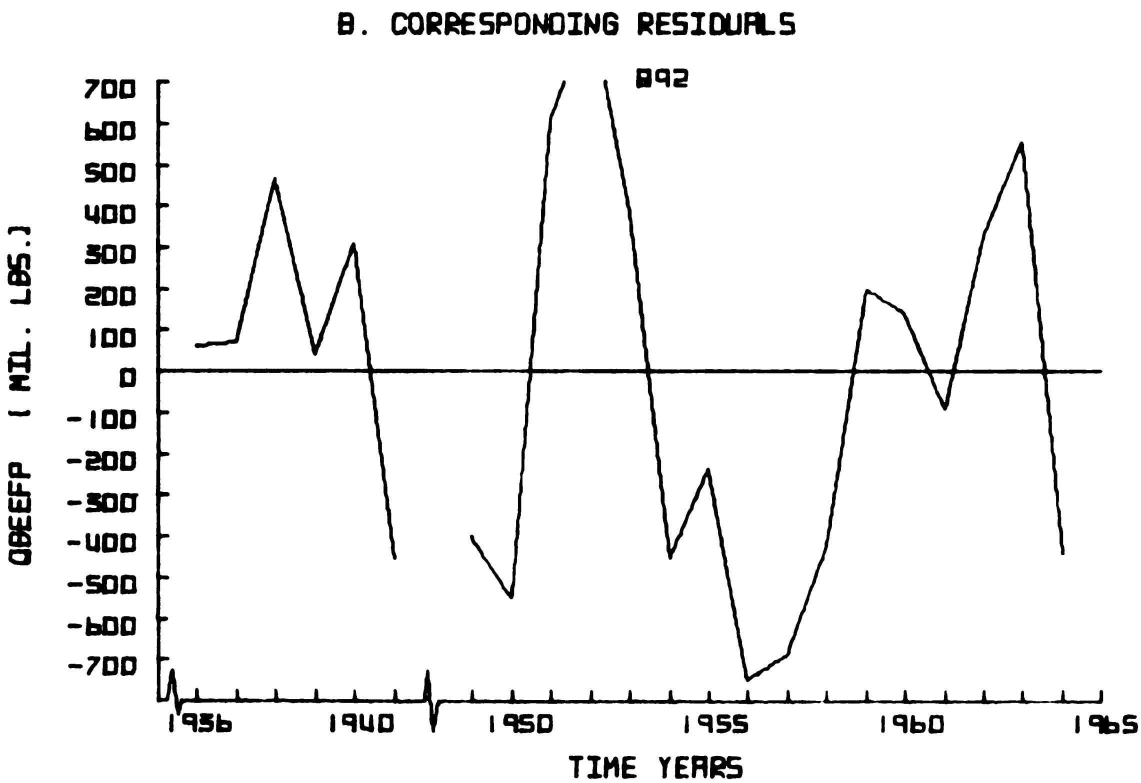


FIGURE 4.5 STRUCTURAL EQUATION 4. INVENTORY DEMAND FOR BEEF CATTLE RETAINED FOR FEEDING AT THE FARM

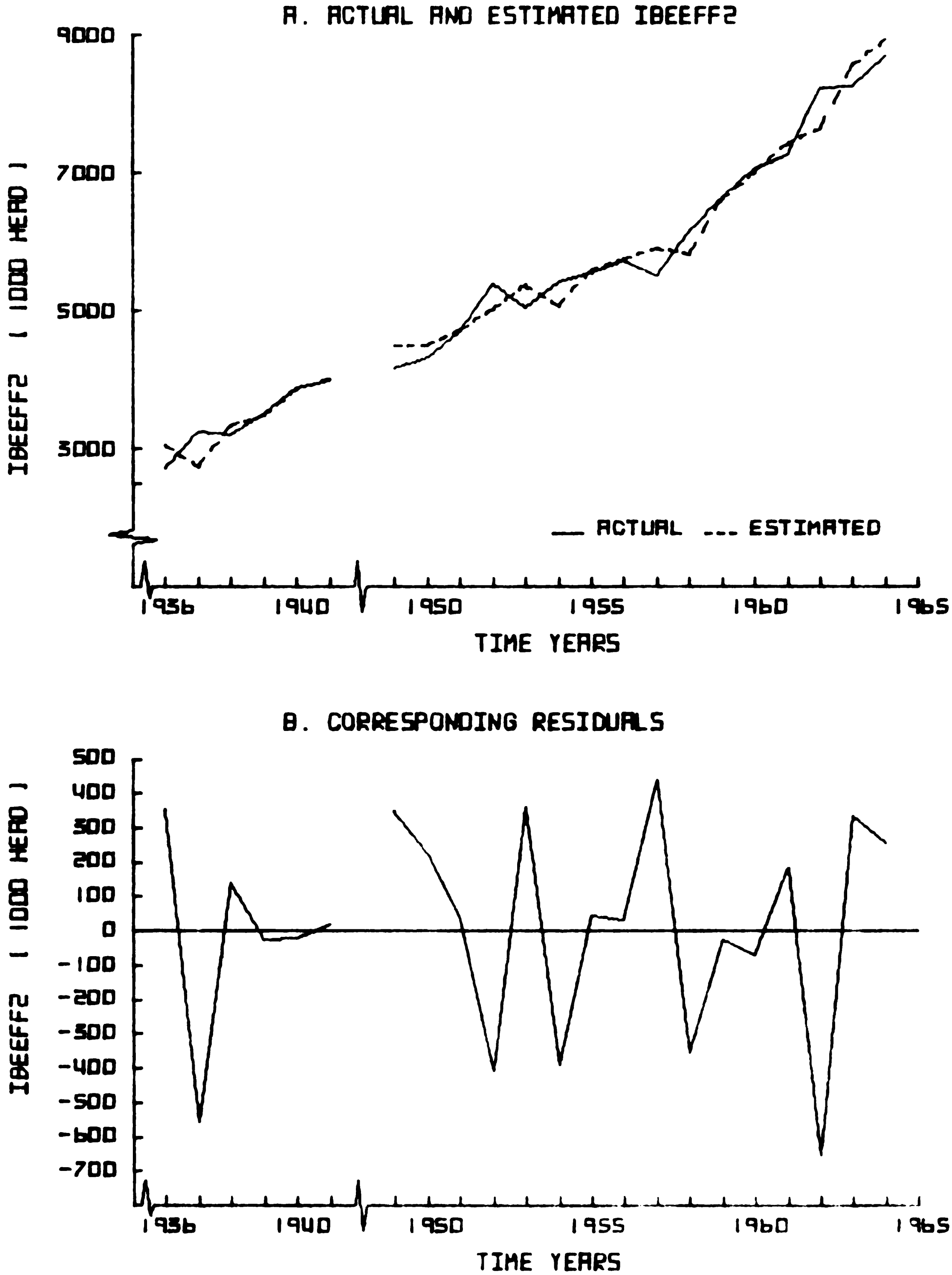


FIGURE 4.6 STRUCTURAL EQUATION 5. INVENTORY DEMAND FOR BEEF CATTLE NOT-RETAINED FOR FEEDING AT THE FARM

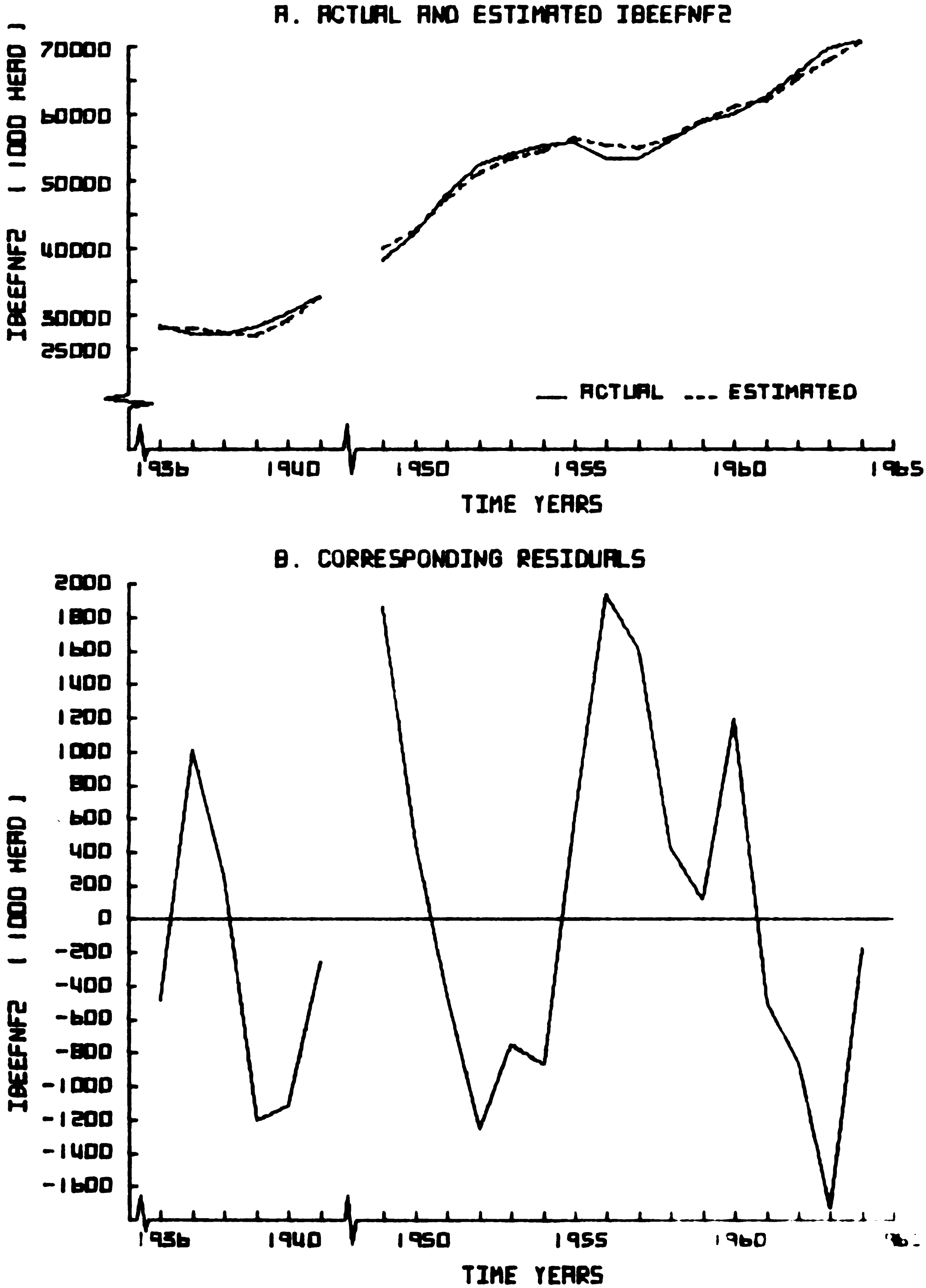
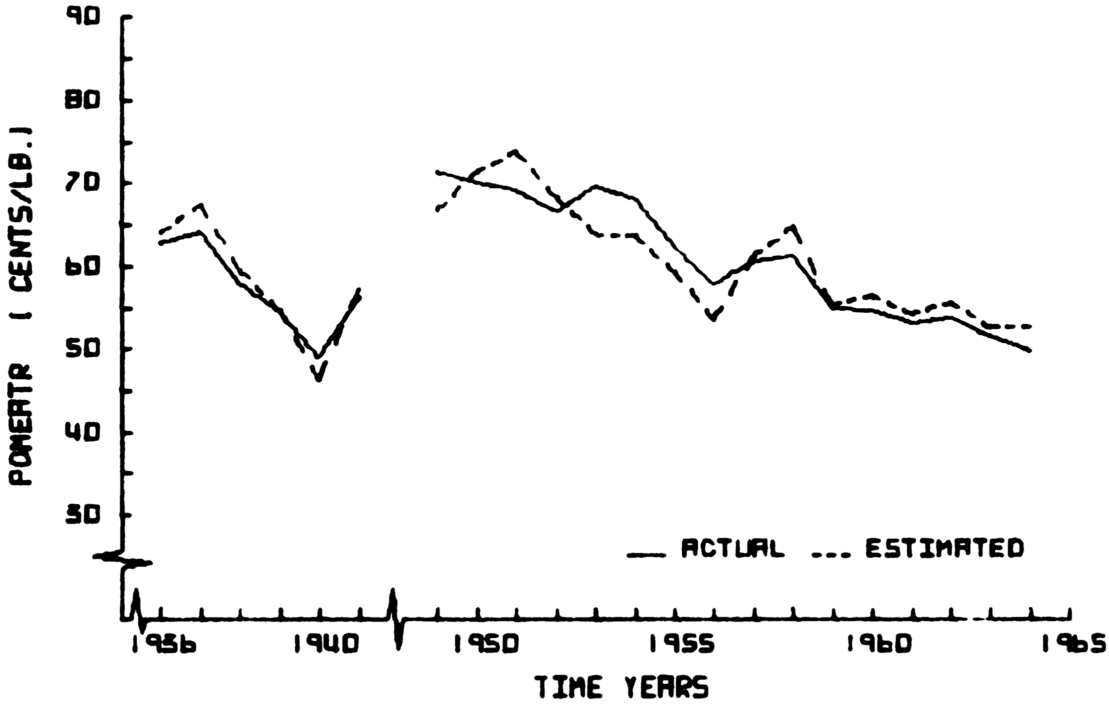


FIGURE 4.7 STRUCTURAL EQUATION 6. DEMAND FOR OTHER MEAT AT RETAIL

A. ACTUAL AND ESTIMATED POMEATR



B. CORRESPONDING RESIDUALS

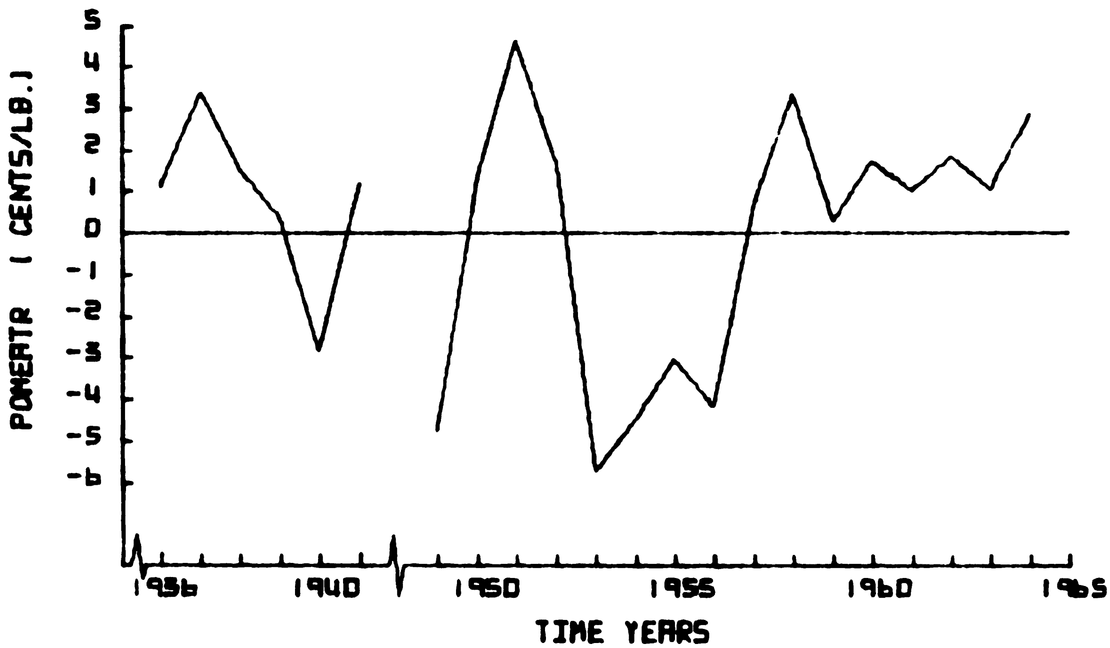
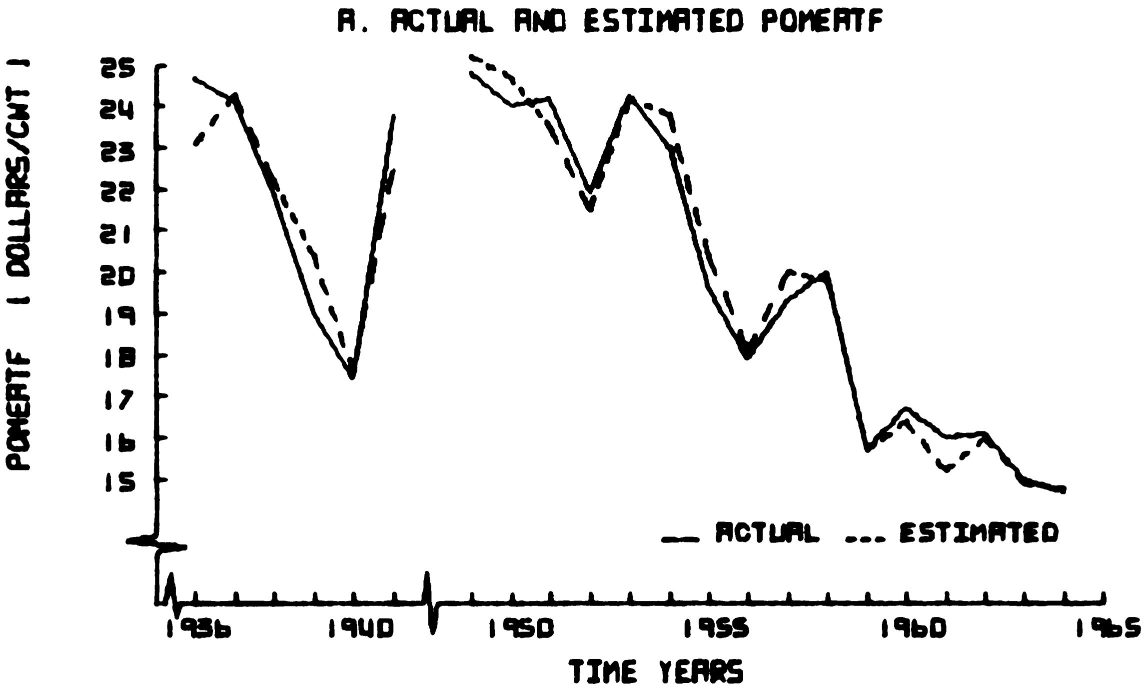


FIGURE 4.8 STRUCTURAL EQUATION 7. MARKETING IN THE OTHER LIVESTOCK-MEAT SECTOR



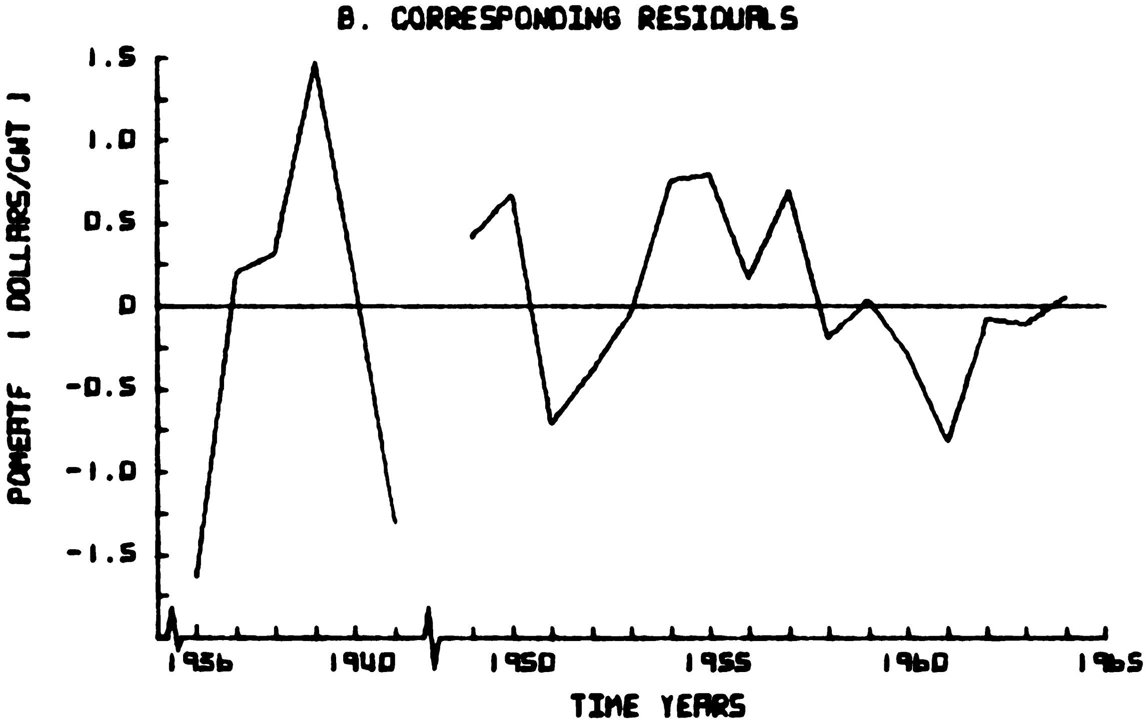
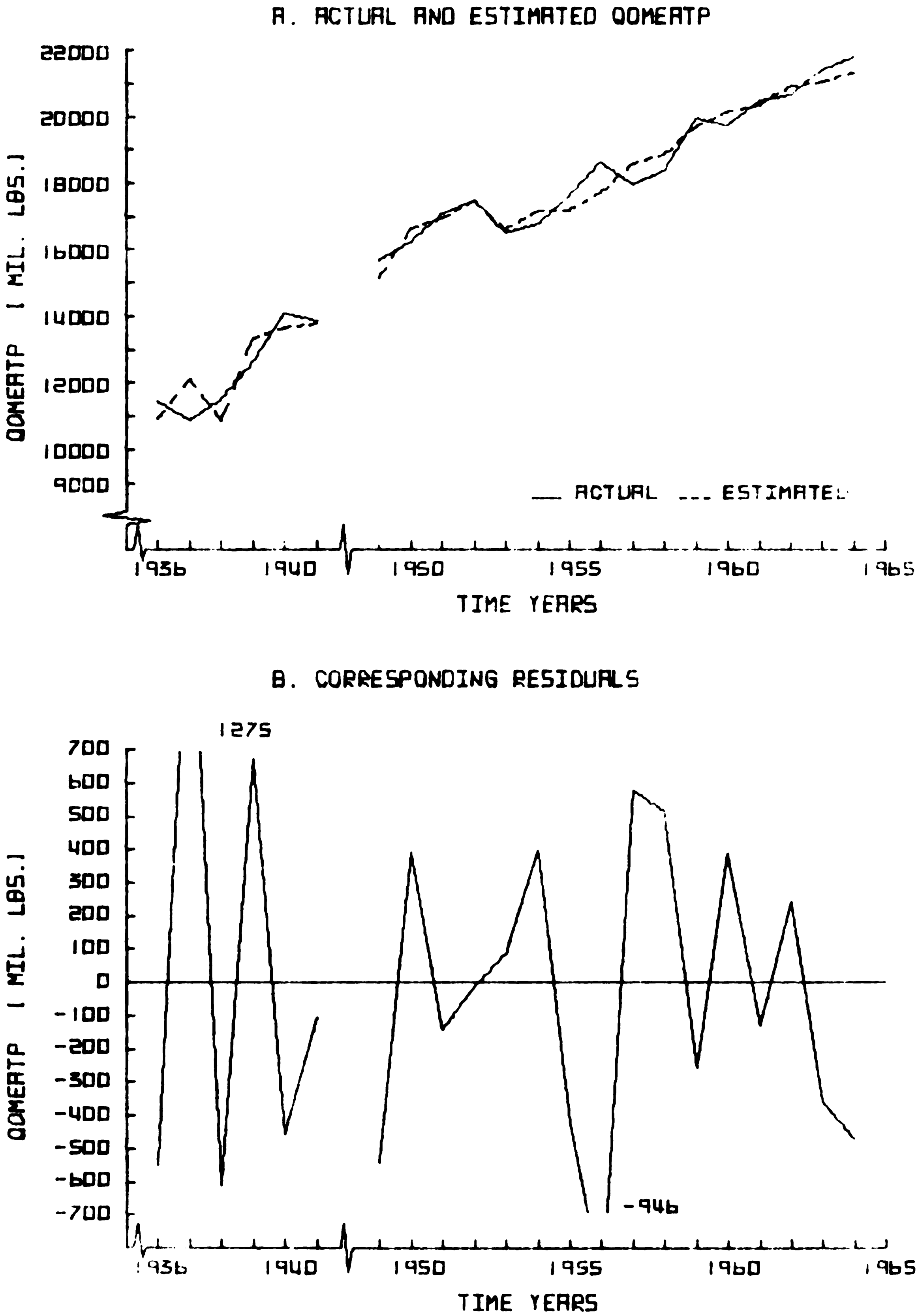


FIGURE 4.9 STRUCTURAL EQUATION B. SUPPLY OF OTHER LIVESTOCK AT THE FARM



PBEEFR changes over the sample period.

Marketing in the Cattle-Beef Sector (Figure 4.3). A relatively closer fit was obtained for PBEEFF than for PBEEFR above, as indicated by R^2 = .97. The estimated PBEEFF moved in the same direction as the observed variable except for 1938. The largest estimated errors occurred in 1952, 1958, and 1962. The pattern of the residuals appears reasonably random so that apparently systematic changes in PBEEFF have been "explained" by this structural relation.

Supply of Beef Cattle at the Farm (Figure 4.4). An R^2 = .98 was calculated, so in terms of explaining variations in QBEEFP, this relation performed well over the sample period. The estimated series missed the direction of the changes in QBEEFP most noticeably in 1939, 1951, and 1954; but otherwise the time path of the estimate was directionally accurate. In absolute terms, the estimates deviated from their actual values most substantially in 1950-52, 1956-57.

Inventory Demand for Beef Cattle Retained for Feeding at the Farm (Figure 4.5). In 1937, 1953, and 1957, the change in estimated IBEEFF2 was in the opposite direction from the actual series, and residuals were the highest in 1937, 1957, and 1962. Overall, the R^2 = .97, so the relation was fit reasonably well in terms of IBEEFF2. (Two variables, CONSTANT and POMEATF, were not statistically significant at a high level in this relation, however.) The residuals appear to be somewhat negatively serially correlated, since the residuals oscillate frequently (note that the D. W. statistic is greater than 2, Table 4.4).

Inventory Demand for Beef Cattle Not-Retained for Feeding at the Farm (Figure 4.6). A very high R^2 was obtained for the relation, $R^2 = .99$, so in terms of IBEEFNF2, most of the variation was explained by the specified relation. All turning points in IBEEFNF2 were reflected by the estimated series except for a slight error in 1937. The largest residuals were for 1949, 1956-57, and 1962, but relatively those residuals represented less than a 2 percent error except for 1949.

Demand for Other Meat at Retail (Figure 4.7). According to the calculated R^2, this relation was fit the least-well of any: $R^2 = .81$, based on 3SLS(2SLS). The POMEATR series was quite cyclical over the sample period, and even with the low R^2, the estimated series followed the actual series reasonably well. The estimated series missed on direction only in 1950-51, 1954 and 1960. The residuals appear somewhat cyclical in the postwar period, thus implying that some systematic influences were not adequately accounted for in the specified relation.

Marketing in the Other Livestock-Meat Sector (Figure 4.8). Relatively, the cyclical pattern of POMEATF was explained reasonably well as indicated by an $R^2 = .96$. The direction of change was estimated incorrectly for 1937, 1951 and 1958. The residuals appear less cyclical in this case than for POMEATR, i.e., more random, as desired. Residuals were relatively large for 1936, 1939, 1941, and 1961.

Supply of Other Livestock at the Farm (Figure 4.9). The postulated supply relation for other livestock which contained only predetermined explanatory variables seemed to explain a high proportion of the variation in QOMEATP, as indicated by $R^2 = .97$. Several small directional errors occurred in 1937-38, 1941, 1957 and 1960. The residuals were largest for 1937 and 1956, and they appear non-random, the frequent oscillations indicating negative serial correlation. (Note that the D. W. statistics is about 2.9, Table 4.8. It should be noted also that equations of this type, based on distributed lag expectation models, tend inherently to have disturbances which are negatively serially correlated, under generally plausible assumptions.)

When the structural form relations are evaluated in the above manner, i.e., focusing upon a particular (normalizing) endogenous variable, then these (3SLS(2SLS)) fitted relations generally explain a high proportion of the variations in those variables. Combined with the general plausibility and the statistical significance of the estimated coefficients, then the overall fitted model would appear to represent the aggregate behavior of the underlying "behavior units" reasonably well.

Reduced Form Estimation and Forecasts

The major purpose of this study was to prescribe an economic (and statistical) model to represent the endogenous mechanism within the cattle-beef sector and interrelationships with the other livestock-meat sector. Once the underlying structural system was specified and equations estimated then a secondary objective was to translate information pertaining to the structural model equations into forecasting mechanisms. As has already been discussed, given a complete model, one can readily obtain the reduced form of the model, which states each of the current endogenous variables as a function of only the predetermined variables in the system (plus a disturbance). The reduced form system is thus in itself a one-period forecasting mechanism.

It is instructive to note the reduced form as follows (as previously defined):

$$A^{-1}AY + A^{-1}BX + A^{-1}U = 0 \qquad \text{(i)}$$

or

$$Y + \Pi X + V = 0 \qquad \text{(ii)}$$

From (i) it is easily seen that each element of Π (reduced form coefficient) is, in general, a function of all the structural coefficients in a row of A^{-1} and in a column of B; and also that each reduced form disturbance is a linear function of all the contemporaneous disturbances. Further, each derived reduced form coefficient is, in general, a non-linear function of the structural coefficients. A knowledge of the derivation of the reduced form coefficients is important because it may commonly be true that even small sampling errors in the individual structural coefficients may build up into substantial sampling errors in the derived reduced form coefficients. Theoretically, it has been established that the estimated Π will be consistent if the estimated A and B coefficients are consistent. Unfortunately, this asymptotic property is of limited consolation in typically small sample analyses.

Ideally, one would expect a "well-fit" structural model to produce a similarly well-fit reduced form system. Yet in practice, the ideal situation may not be realized. This digression was in part a defense for the structural model estimates obtained above, because the reduced form coefficient estimates did not, in all cases, generate the endogenous variables as closely as was desired, a priori (as indicated by the reduced form equation estimated R^2's; see Appendix B).

However, in order to further indicate (in addition to the estimates presented in Appendix B) the possible usefulness of our reduced form parameter estimates, we explore how our fitted model <u>would</u> <u>have</u> performed (as a forecasting tool) over the sample period, 1936-41, 1949-63; given first, some initial values for <u>all the predetermined</u> variables, and second, the actual values for each of the <u>exogenous</u> (excludes our lagged endogenous) variables for each period thereafter, i.e., until 1963. (Presumably, if one were to forecast into some future periods, using a statistical model, then he would have to prescribe independent values for the exogenous variables. We chose to "forecast", <u>ex post</u>, the sample period fitted so as to utilize observed exogenous variables, and thereby examine the nature of the reduced form mechanism derived from our complete structural model.)

The presence of lagged endogenous variables in the reduced form (also in the structural equations) provided us with a choice; that is, we could either use the observed values at each point in time, and thus get a series of one-year "forecasts" (which is in fact what the reduced form R^2's in Appendix B do refer to); or we could instead use the previous period forecasts of the corresponding endogenous variables as estimates of the "current" period lagged endogenous variables. We chose the latter alternative so as to explore how the reduced form would have generated the endogenous variables assuming only the exogenous factors were "known" (or forecast accurately) over the "forecast" period.

This procedure was operationalized readily by considering the (rewritten) reduced form equations,

$$Y = \Pi X + V \tag{iii}$$

as a partitioned form, ~~as~~

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} \Pi_1 & \Pi_2 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + V \tag{iv}$$

$$= \Pi_1 X_1 + \Pi_2 X_2 + V \tag{v}$$

where Y_1 and Y_2 are the forecast (endogenous) variables of the system: X_1 are the lagged endogenous "estimated" variables, i.e., $X_1(t) = Y_2(t-1)$; X_2 are the exogenous variables; and Π (Π_1 and Π_2) are the appropriately rearranged reduced form coefficient estimates. As indicated above, the initial values for both X_1 and X_2 were the 1936 actual values; X_2 continued to take on actual values thereafter, and X_1 values were successively replaced by the previous period Y_2 forecasts. Thus, successive "forecasts" were obtained for 1936,...,1941, 1949, ...,1963.[18]

The results of this exploration are presented graphically in Figures 4.10 to 4.19. Except for 1936 and 1949 we stress that these "forecasts" are not simply a series of one-year

[18]Because the 1942 to 1948 observations were excluded from our original sample, we also excluded that period in this section. Thus, we "restarted" the forecast series beginning in 1949, i.e., X_1 and X_2 in 1949 are observed predetermined variable values.

forecasts, but they are successive forecasts which utilize forecast estimates for the included lagged endogenous variables. We also emphasize that this exploration is only one possible way to appraise the reduced form estimated model.

In general, the forecast series followed the time-path patterns of the actual series; however, absolute deviations of the estimated series from the actual series were generally substantial. We regard the former characteristic a strength rather than a weakness of the set of forecast mechanisms as a whole; but the latter characteristic negates the usefulness of individual equations for precise forecasting purposes. Results of this exploration are summarized briefly below for each equation.

Price of Beef at Retail (PBEEFR) (Figure 4.10). The absolute deviations of the PBEEFR forecasts were particularly large for both the 1936-1941 and 1949-1963 sub-periods. (Since forecast values of the lagged endogenous variables were fed-back into the system, then errors in forecasting these variables is another source of error that influences successive forecasts). Other than the fact that this forecast series did not systematically deviate from the general path of the actual PBEEFR series, this forecasting equation did not perform well.

Price of Beef Cattle at the Farm (PBEEFF) (Figure 4.11). The characteristics of both the actual and the forecast series for PBEEFF are quite similar to those above for PBEEFR. Devia-

FIGURE 4.10 REDUCED FORM EQUATION 1. PRICE OF BEEF AT RETAIL

A. ACTUAL AND ESTIMATED PBEEFR

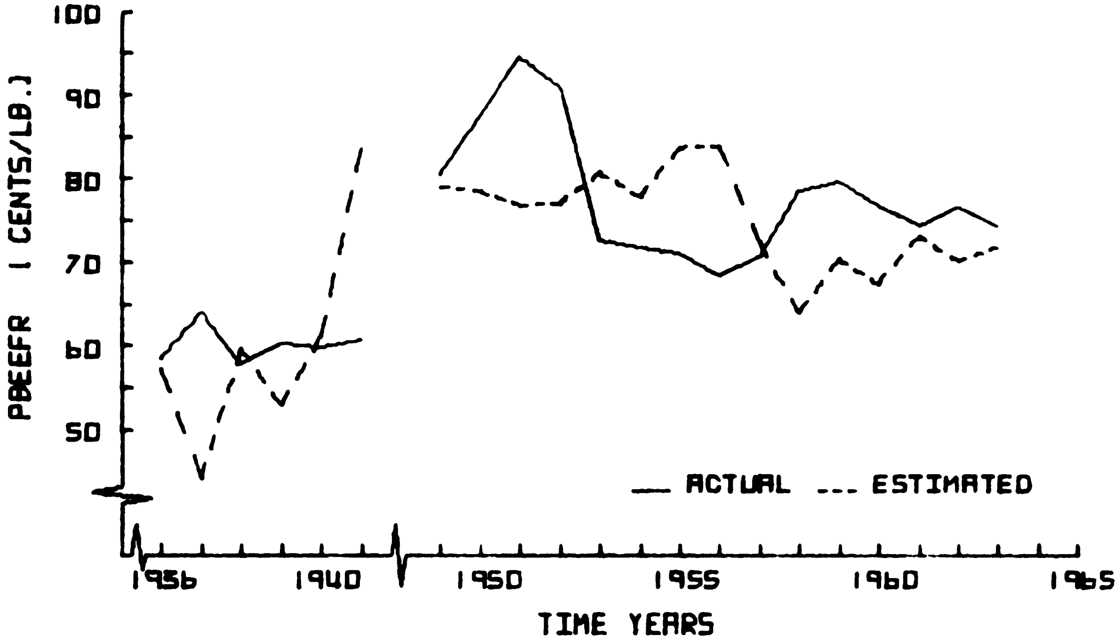


FIGURE 4.11 REDUCED FORM EQUATION 2. PRICE OF BEEF CATTLE AT THE FARM

A. ACTUAL AND ESTIMATED PBEEFF

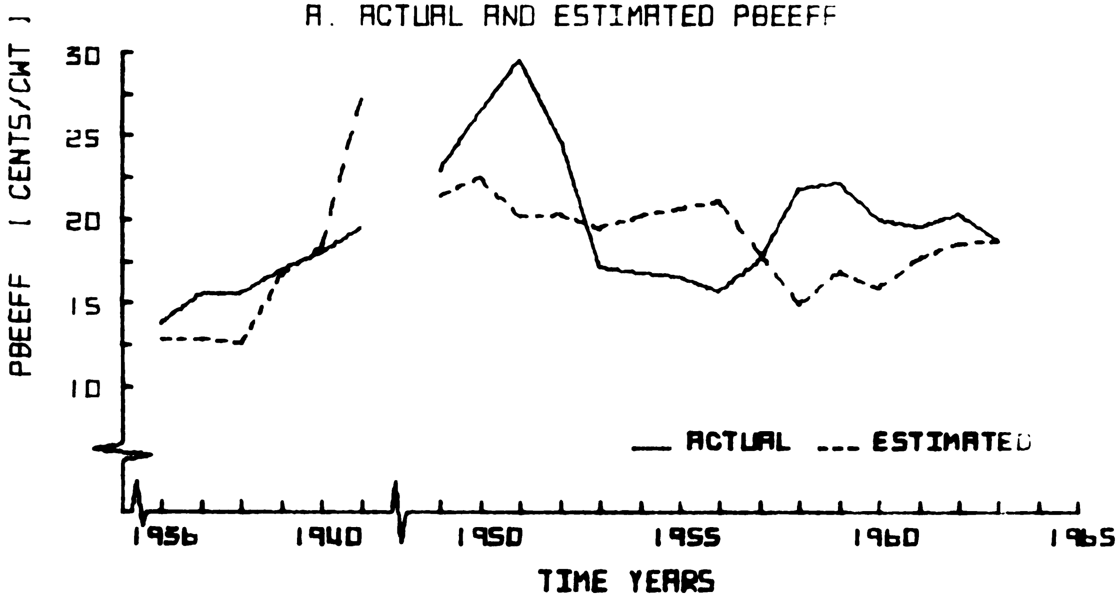


FIGURE 4.12 REDUCED FORM EQUATION 3. QUANTITY OF BEEF PRODUCED FOR SLAUGHTER

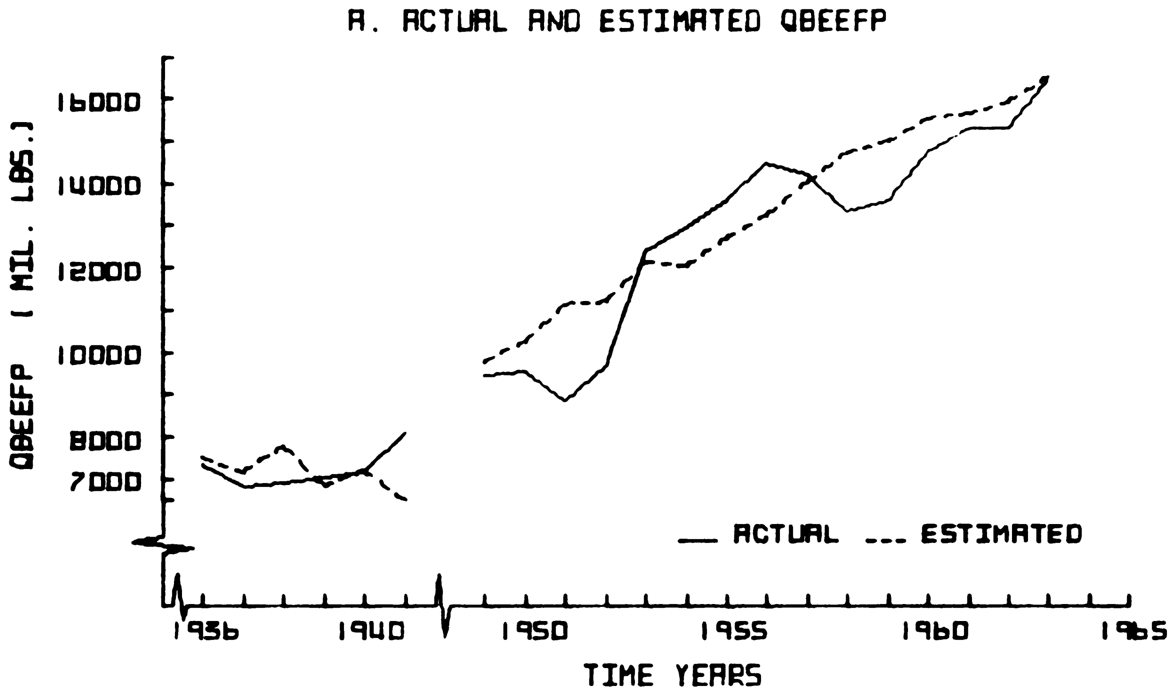


FIGURE 4.13 REDUCED FORM EQUATION 4. INVENTORY OF BEEF CATTLE RETAINED FOR FEEDING

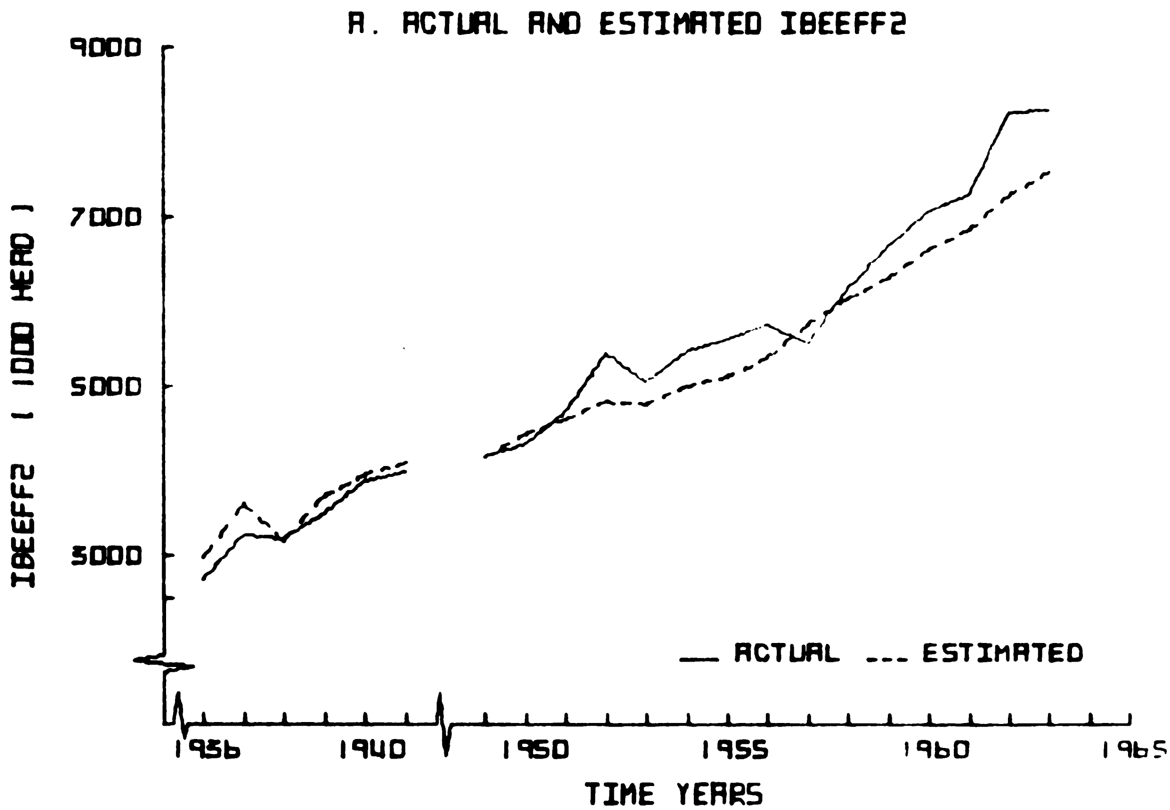


FIGURE 4.14 REDUCED FORM EQUATION 5. INVENTORY OF BEEF CATTLE NOT-RETAINED FOR FEEDING

A. ACTUAL AND ESTIMATED IBEEFNF2

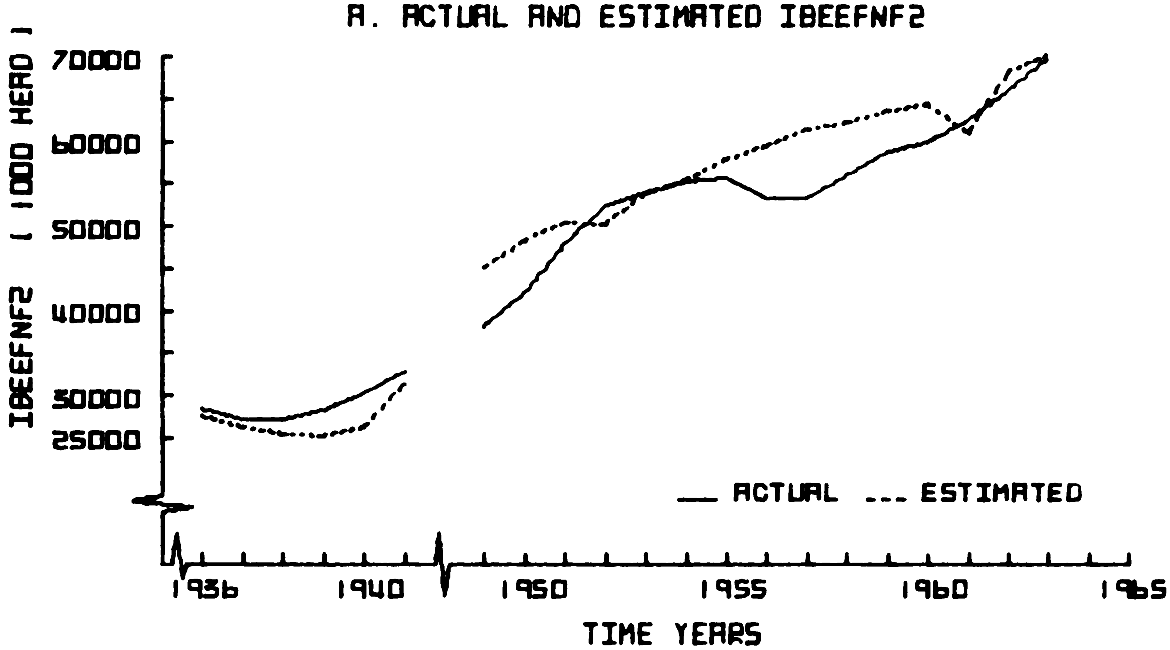


FIGURE 4.15 REDUCED FORM EQUATION 6. PRICE OF OTHER MEAT AT RETAIL

A. ACTUAL AND ESTIMATED POMEATR

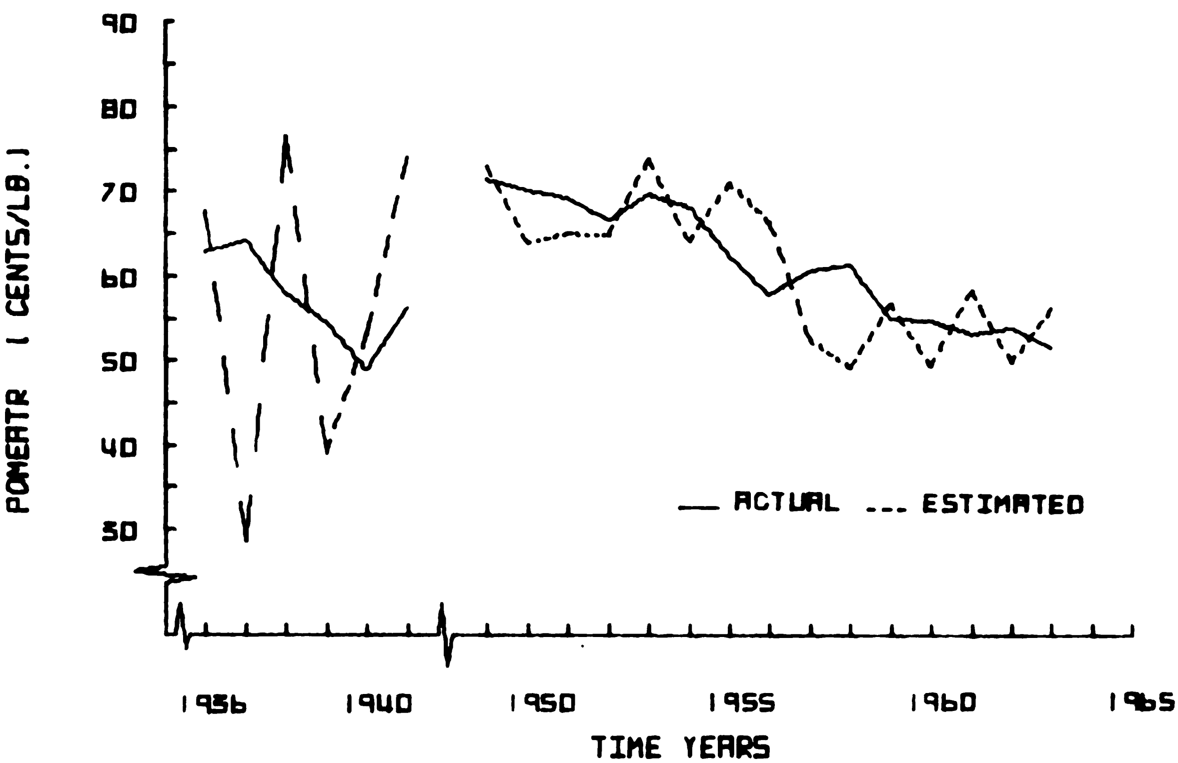


FIGURE 4.16 REDUCED FORM EQUATION 7. PRICE OF OTHER LIVESTOCK AT THE FARM

A. ACTUAL AND ESTIMATED POMEATF

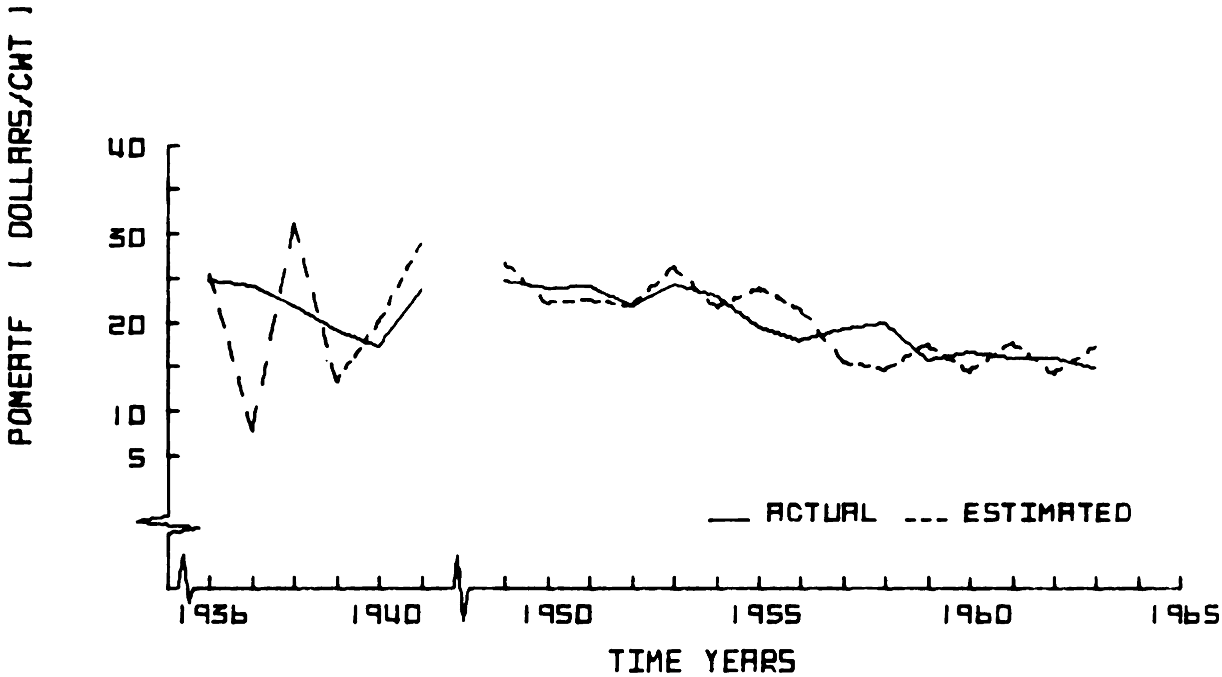


FIGURE 4.17 REDUCED FORM EQUATION 8. QUANTITY OF OTHER MEAT PRODUCED

A. ACTUAL AND ESTIMATED QOMEATP

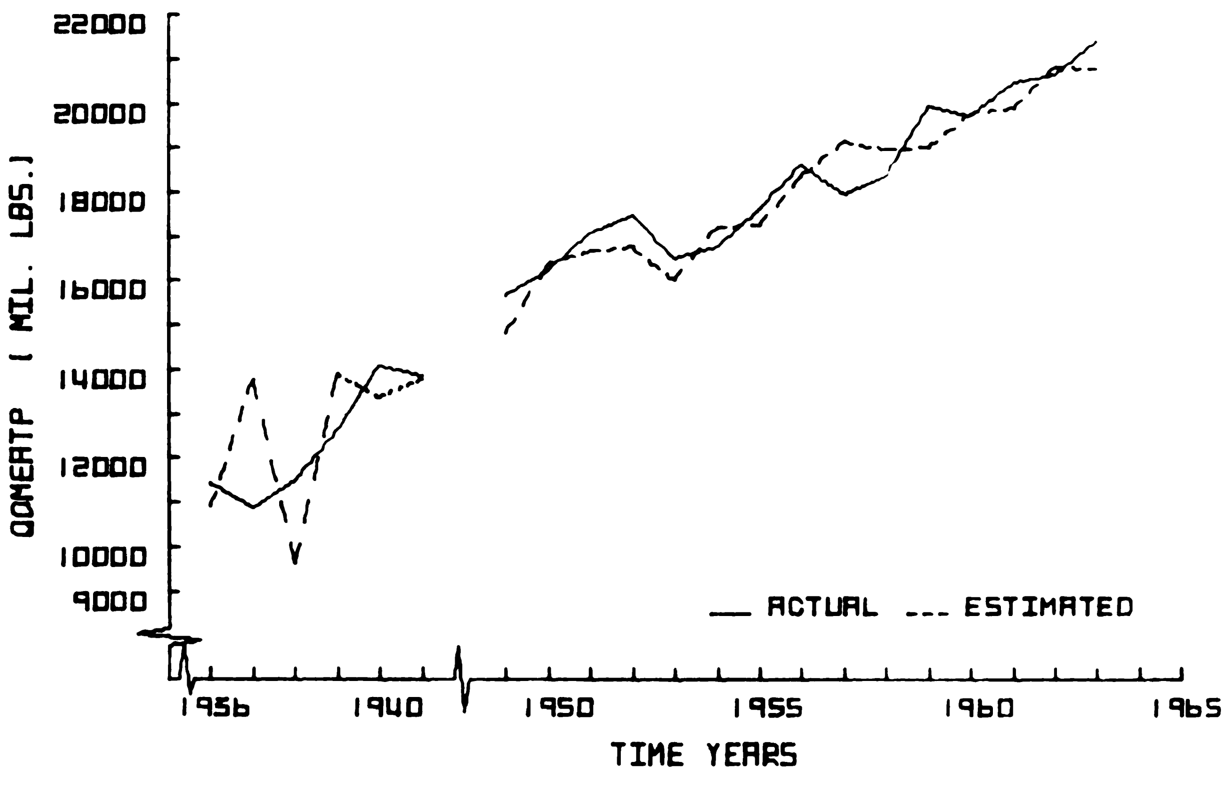


FIGURE 4.18 REDUCED FORM EQUATION 9. QUANTITY OF OTHER MEAT CONSUMED

A. ACTUAL AND ESTIMATED QOMEATC

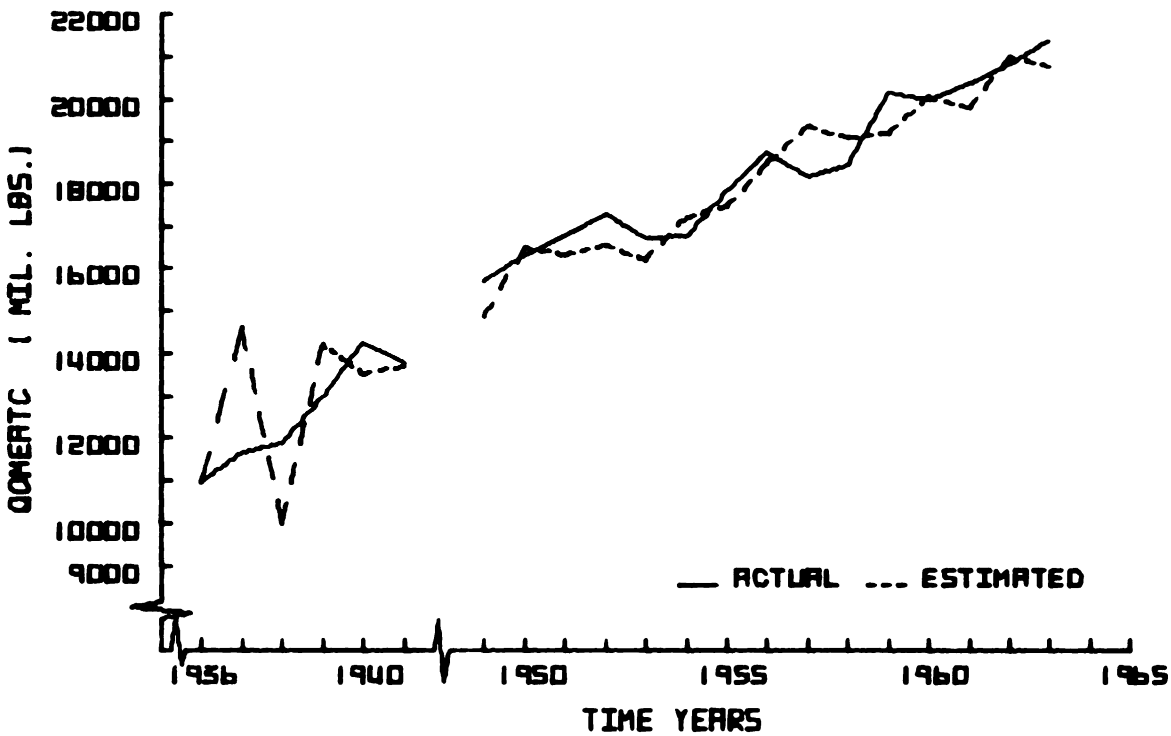
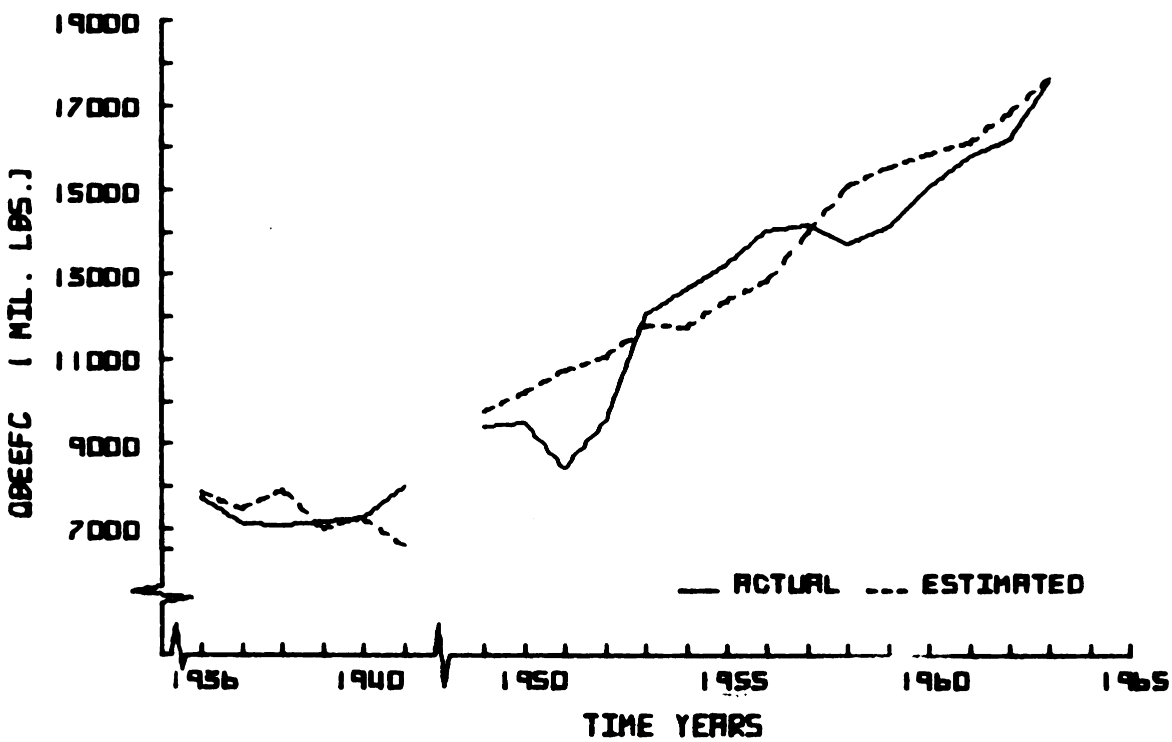


FIGURE 4.19 REDUCED FORM EQUATION 10. QUANTITY OF BEEF CONSUMED

A. ACTUAL AND ESTIMATED QBEEFC



tions of the forecasts from the actual series were substantial. This was disappointing, but it is again noteworthy that the forecast series did not systematically deviate from the over-all time-path pattern of PBEEFF.

Quantity of Beef Produced for Slaughter (QBEEFP)(Figure 4.12). A reasonably smooth time-path pattern for QBEEFP was generated with our fitted reduced form mechanism. The cyclical nature of this variable was not explained by the forecasting mechanism, but the general trend was picked up reasonably well.

Inventory of Beef Cattle Retained for Feeding (PBEEFF2) (Figure 4.13). The forecast series for IBEEFF2 essentially paralleled the actual series throughout the 1936-41, 1949-63 sample period, with the forecasts generally below the actual values.

Inventory of Beef Cattle Not-Retained for Feeding (IBEEFNF2) (Figure 4.14). The forecast series followed the actual series generally well for IBEEFNF2, but again deviations were large on the average. Cyclical characteristics of the IBEEFNF2 actual series were not generally reflected in the forecast series.

Price of Other Meat at Retail (POMEATR) (Figure 4.15). This forecast series was severely oscillitory over the sample period, yet the estimates generated followed the pattern of the actual series throughout the sample period. In the 1949-

63 sub-period, the oscillations deviated considerably less from the actual series than during the earlier 1936-41 sub-period; which indicates greater applicability in the more recent past.

Price of Other Livestock at the Farm (POMEATF) (Figure 4.16). The pattern of the forecast series for POMEATF was quite similar to that for POMEATR, with no systematic deviations from the actual series. Also, this estimated series was smoother in the latter part of the sample period. General trends are seemingly explained well by this forecasting mechanism.

Quantity of Other Meat Produced (QOMEATP) (Figure 4.17). An oscillitory path was generated for QOMEATP; but the forecasts followed the actual series closely throughout the sample period, particularly for the 1949-1963 sub-period.

Quantity of Other Meat Consumed (QOMEATC) (Figure 4.18). This forecast series for QOMEATC is actually the same as the above relation for QOMEATP, except for a predetermined amount. Namely, these estimates differ from those for QOMEATP by the amount of NOMIMPORT. Thus, this series has characteristics similar to the above series.

Quantity of Beef Meat Consumed (QBEEFC) (Figure 4.19). Like the above relation, no additional information is contained in this forecast series, since QBEEFC differs from QBEEFP by a predetermined value, NBIMPORT.

The fact that most of the "forecast" series did not systematically diverge from the actual series over the sample period as a whole seems to be a strength of the mechanism. On the shorter run forecast patterns seem generally inferior to what one might have expected from, for example, simple unrestricted reduced form estimates.

A somewhat more straightforward application of reduced form equations is to forecast (conditionally) outside the sample period for periods for which data are available, e.g., all the 1964 data are now available for the variables used in this study. Thus, using the 1964 values of the predetermined variables (and the corresponding 3SLS(2SLS) reduced form coefficient estimates we obtain "forecasts" for 1964. As another example of how the forecasting mechanism of this study may be expected to perform, the estimated ("forecast") and actual 1964 values (of the endogenous variables) are presented in the table below (Table 4.12). (These forecasts are still <u>ex post</u> since 1964 data are reported; but conditional upon having accurately measured (or estimated) the predetermined explanatory variables prior to 1964, we can regard this "test" as somewhat stronger than using only sample data.) As yet, appropriate statistical tests for forecasts from simultaneous equations estimation procedures have not been developed; thus, we present only our "point estimate" results at

Table 4.12

3SLS(2SLS) REDUCED FORM ONE-PERIOD FORECASTS (EX POST) FOR 1964 AND RELATED STATISTICS

	Endogenous Variables	Units	Actual Values 1963	Actual Values 1964	Forecast Values 1964	Error 1964	Actual Change 1963-64	Forecast Change 1963-64
1	PBEEFR	¢/lb.	75.91	71.97	79.59	7.62	- 3.94	19.66
2	PBEEFF	$/cwt.	18.77	16.82	18.51	1.69	- 1.95	4.91
3	QBEEFP	mil. lbs.	16423.	18424.	17848.	-576.	2001.	143.
4	IBEEFF2	1000 head	8988.	9483.	9559.	121.	50.	302.
5	IBEEFNF2	1000 head	69846.	71000.	71428.	428.	1.329	5226.
6	POMEATR	¢/lb.	51.57	49.91	61.66	11.75	- 1.66	28.04
7	POMEATF	$/cwt.	14.96	14.71	19.64	4.93	.25	7.21
8	QOMEATP	mil. lbs.	21549.	21934.	21459.	-475	385.	108.

this time.

The 1964 forecasts summarized in Table 4.12 are disappointingly poor, in general; and these 3SLS(2SLS) forecasting equations are not considered adequate for one-period forecasting.

In summary, our consideration of the forecasting potential of the fitted reduced forms has been limited to the 3SLS(2SLS) results (in Appendix B); an exploration that led to successive (versus single-period) forecasts; and finally *ex post* conditional forecasts for one period outside the sample period. We regard the mechanism as a whole as possessing some internally consistent characteristics (based on the generated forecasts, see Figures 4.10 to 4.19); but some individual equations did not "forecast" well over the sample period. Further analyses are needed before the forecasting usefulness of the derived reduced form equations can be fully ascertained.

Comparison of Results from This Study with Other Studies

Some comparisons of the results of this study with other related research results are discussed in this section. Comparisons of estimated price and income elasticities for beef retail demand relations are presented in Table 4.12, and estimated price elasticities for beef supply relations are presented in Table 4.13.[19]

When comparing results from different studies one must recognize that important differences usually exist among pro-

[19] See following page.

cedures used in different[20] analyses. Manderscheid suggests that the following types of measurement problems and their implications are particularly critical when interpreting elasticity estimates: a) nature of the observations (e.g., time series or cross section data), b) adjustment period, c) sample period, d) stage in the marketing process (e.g., farm or retail), e) controlled variables, f) functional form (e.g., linear, logrithmic, or polynomial), and g) estimation procedure. Some of these differences are briefly indicated in the following summary tables,

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[19]All the analyses compared were based on annual time series data. The references cited in Table 4.12 are the following: (a) Wallace, T. D. and Judge, G. G.: "Econometric Analysis of the Beef and Pork Sectors of the Economy," Stillwater: Oklahoma State University, Tech. Bull. T-75, August 1958; (b) Nordin, J. A., Judge, G. G. and Wahby, O.: "Application of Econometric Procedures to the Demands for Agricultural Products," Ames: Iowa State College, July 1954; (c) Fox, K. A.: "Demand Functions for Livestock Products," Econometric Analysis for Public Policy, Ames, Iowa, 1958, pp. 66-69; and (d) Breimyer, H. F.: "Demand and Prices for Meat. Factors Influencing Their Historical Development," USDA, Tech. Bull. No. 1253, December 1961.

Those studies cited in Table 4.13 are the following: (a) Cromarty, W. A.: "An Econometric Model of the United States Agriculture," Journal of the American Statistical Association, Vol. 54, September 1959, pp. 556-574; and (b) Wallace, T. D. and Judge, G. G.: op.cit., 1958.

A more complete summary of each of these (and other) studies was made in: Buchholz, H. E., Judge, G. G., and West, V. I.: "A Summary of Selected Estimated Behavior Relationships for Agricultural Products," Urbana: University of Illinois, Research Report AERR-57, October 1962.

[20]Manderscheid, L. V.: "Some Observations in Interpreting Measured Demand Elasticities," Journal of Farm Economics, Vol. 46, February 1964, pp. 128-136.

Table 4.13

COMPARISON OF ESTIMATED RETAIL DEMAND PRICE AND INCOME ELASTICITIES FOR BEEF WITH OTHER STUDIES[a]

Source	Functional Form	Sample Period	Estimation Procedure	Estimated Elasticities[e]			
				ε(Quantity/ Price)	ε(Quantity/ Income)	ε(Price/ Quantity)[d]	ε(Price/ Income)[d]
Wallace & Judge (Model I)	Linear logs	1925-41, 1947-55	LISE	-1.36	.97		
" (Model II)	"	"	"	- .87	.59		
" (Model I)	"	"	2SLS	- .77	.60		
" (Model II)	"	"	"	- .77	.58		
"	"	"	OLS	- .76	.58		
Nordin, Judge & Wahby	"	1922-41	LISE	-3.23	-.63		
"	"	"	Indirect-Least Squares	- .77	.65		
"	"	"	OLS	- .96	.33		
Fox	Change in logs	1925-41	Indirect-Least Squares	-1.04[b]	.85[c]	-.96	.82
Breimyer	Linear logs	1948-60	OLS	- .64[b]	1.04[c]	-1.57	1.64
"	"	1921-41, 1948-60	OLS	-1.0[b]	.76[c]	-1.0	.76
This Study	Linear arithmetic	1936-41, 1949-63	3SLS(2SLS)	-.959[b]	1.218[c]	-1.042	1.270
"	"	"	2SLS	-.871[b]	1.183[c]	-1.149	1.359
"	"	"	UNK	-.869[b]	1.183[c]	-1.150	1.360
"	"	"	LISE	-.376[b]	1.017[c]	-2.662	2.708
"	"	"	OLS	-.872[b]	1.184[c]	-1.147	1.359

[a]Sources are noted at the beginning of this section. [b]Reciprocals of ε(Price/Quantity). [c]Ratio of ε(Price/Income) to ε(Price/Quantity). [d]Reported if original study had price as the normalizing variable. [e]Notation is to be read as an elasticity of the first named variable with respect to the second named variable.

but the reader should keep in mind that other differences further complicate the comparability of the selected estimates. A final note is that some of the studies "normalized" on the price variable (as was done in the demand relations here) which means that elasticities (of quantities, in the usual sense) are derivable, *ex post*, only by algebraic transformation of the estimated coefficients. There are a number of valid economic and statistical questions which should be considered when transforming the original estimates.[21] Partly for such reasons, elasticities of price with respect to other variables are also presented in the summary tables when the normalizing variable was a price variable.

In general, comparison of the selected retail demand price elasticities for beef indicates that the estimates from this study are "intermediate" within the range of the estimates presented. Note that the LISE estimates have the largest range, i.e., a low of -.376 and a high of -3.23; this perhaps indicates that the LISE estimator is more sensitive to specifications in the underlying models. A more detailed appraisal of the differences among the models, in addition to the indicated differences,

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[21]See, for example: Houck, J. P.: "The Relationship of Direct Price Flexibilities to Direct Price Elasticities," *Journal of Farm Economics*, Vol. 47, August 1965, pp. 789-792, for a discussion (and related references) of some of the relationships between elasticities and their reciprocals. Houck's main argument does not, however, apply directly to our own procedures since, while we did normalize on price, the effects of closely related commodities were represented in our equations not by quantities but by *their* prices.

might lead to some tentative conjectures as to the wide range of the LISE estimates.

With regard to the income elasticity estimates, the estimates from this study (derived as the ratio: ε (PBEEFR/DISPY) $\div$ ε (PBEEFR/QBEEFC)) were generally larger than the other estimates. This result was expected insofar as the disposable income (deflated) variable in this study was specified to represent the combined effects of income and population, because these two variables were highly correlated over the sample period. Another factor is that DISPY (in this study) was also highly correlated with "time"; i.e., t = 1 for 1936, 2 for 1937, ...; so DISPY possibly picked-up trend effects. A priori, each of these variables (income, population, and "time") was expected to have some positive association with the level of beef consumption over the sample period. Thus, it is likely that the DISPY elasticity estimates from this study are indeed overestimates of the true income elasticity.

Turning to Table 4.14 and the estimated price elasticities for farm supply of beef, a most obvious shortcoming is the dearth of comparative estimates. The selection presented, while not complete, seems to be representative of those which are generally accessible for beef cattle. Statistical analyses of the supply response relations of farm commodities, in general, and of beef cattle, in particular, have not yet received adequate attention in the profession.

Table 4.14

COMPARISON OF ESTIMATED FARM (AND RETAIL) ONE-YEAR SUPPLY PRICE ELASTICITIES FOR BEEF WITH OTHER STUDIES[a]

Source	Functional Form	Sample Period	Estimation Procedure	Estimated Elasticities: ε (Quantity/ Price)
Cromarty	Linear arithmetic	1929-53	LISE	.037
Wallace & Judge (Model IIa- Retail	Linear logs	1925-41, 1947-55	OLS	-.25
" (Model IIb- Retail	"	"	"	.04
This Study	Linear arithmetic	1936-41, 1949-63	3SLS(2SLS)	-.137
"	"	"	2SLS	-.159
"	"	"	UNK	-.152
"	"	"	LISE	-.094
"	"	"	OLS	-.183

[a] Sources are noted at the beginning of this section.

Cromarty's estimate refers to an elasticity of liveweight slaughter of beef with respect to a current price of beef, so we regard his estimate as roughly comparable to our elasticity estimates of carcass weight slaughter production with respect to a current average farm price. However, the Wallace and Judge estimates are both elasticities of mature cattle slaughter with respect to real farm price of beef lagged one year (and also the corresponding equations were postulated as supply of beef at retail relations); hence, their study dealt with different price and quantity components than those of this study.

While the Cromarty estimate was positive, the corresponding t-value of the underlying coefficient was equal to .82, which implies a low level of statistical significance. Similarly, we note that the t-value for the Wallace and Judge -.25 estimate was 2.61, whereas the $t = 1.83$ for the .04 estimate (their variables were specified in logs, so the coefficients are elasticities). The estimated coefficient/standard error ratios in our study were about 3 (see Table 4.14, above), except for LISE. It is informative to note this additional characteristic of the tabled estimates; the reported positive elasticity estimates were generally not statistically significant (based on the t-test as an approximation).

CHAPTER V

SUMMARY AND CONCLUSIONS

This study was a simultaneous equations structural form approach to quantitative analysis of interrelationships within the cattle-beef sector and within the other livestock-meat sector of the United States economy. By studying both sectors simultaneously, a more complete account of relationships between the two sectors was also possible. Both of these sectors were considered as consisting of three inter-connected segments: producer, marketing, and consumer. Although the broad framework corresponding to the cattle-beef and the other livestock-meat sectors was regarded as essentially the same, the internal mechanisms were specified quite differently. Our main focus in this study was directed toward the endogenous mechanism of the cattle-beef sector; thus, we regard the specifications and results corresponding to this sector as the principal contributions of this research.

Relationships were specified in the cattle-beef sector producer-segment to correspond to three basic types of producer-behavior decisions; namely, decisions regarding beef cattle production for slaughter, for inventory to be retained for feeding purposes, and for inventory to be retained for non-feeding purposes. While this type of specification was in part an analytical simplification of the underlying production process, there is also some empirical justification for distinguishing among the above production components. Namely, there are groups of producers who specialize in cow-herd and calf production, stocker operations and feeding enterprises. Even those producers who have integrated these operations can be considered as deciding for each class of animals whether to sell for slaughter, retain for feeding or retain for herd maintenance.

The aggregate composite behavior of marketing firms in the marketing segment was conceived as a simultaneous derived demand for beef cattle on the one hand, and as a supply response (of beef-meat products and services) at retail, on the other hand. For aggregative analytical purposes, a single marketing behavior relationship was therefore specified. The actual marketing process is varied and complex, and admittedly the specification of a single aggregative relationship to represent the behavior of such a wide range of firms is a gross simplification. The acceptance or rejection of such a simplified mechanism depends upon how well that simplified analytical structural relation "performs" within the system as an approximation of aggregate behavior. Aggregate consumers' behavior was summarized in a demand for beef at retail structural equation.

The other livestock-meat sector relationships were specified similarly for the marketing and consuming segments. A major difference was in the producer segment relationships, however. In this case, an underlying distributed lag model was postulated to represent the aggregate behavior of other livestock producers. While a breakdown of other livestock producer segment into slaughter and inventory components was considered, the life cycles of other livestock are markedly different, such that, on an annual basis, it was considered less meaningful to consider inventory at only one period within the year. If a shorter adjustment period were considered, then a framework similar to that specified for beef cattle might have been more appropriate. The empirical results obtained suggest that the postulated relation was reasonably accurate for denoting aggregate behavior over the sample period.

The two sectors, cattle-beef and other livestock-meat, are related principally through price variables; prices corresponding to one sector are specified in equations of the other. To complete the model, two identies were introduced to relate the beef and other livestock consumption and production variables. A difference existed primarily as a result of international trading (but also because of a channeling of meat into military uses and changes in commercial storage). The difference between consumption and production for a given period was defined as net imports and postulated as a predetermined variable in the system. This specification was considered justified mainly on the grounds that institutional factors (outside of the system) largely determined the aggregate difference between civilian consumption and production of livestock meats. The economic and statistical models were specified and summarized in Chapter III (see schematic summary, Tables 3.1 and 3.3).

Several alternative estimators were employed; namely, Three Stage Least Squares (3SLS), Two Stage Least Squares (2SLS), Unbiased Nagar K-Class (UNK), Limited Information Single Equation (LISE), Ordinary Least Squares (OLS), and for experimental purposes, an Iterative-Three Stage Least Squares (I3SLS) procedure. The 3SLS estimator was employed for three sets of "beginning" estimates: 2SLS, UNK and LISE; and these different procedures were referred to as 3SLS(2SLS), 3SLS(UNK) and 3SLS(LISE). The 2SLS, UNK, and LISE estimators are "limited information" single equation methods since some account is made of the equation being embedded in a system (and they are commonly referred to as simultaneous equation estimation procedures). OLS is strictly a single equation procedure in that no account is taken of the equation being embedded in a system. The 3SLS procedure is a "full-information" system method of estimation whereby all the coefficient parameters are estimated simultaneously. While the applicability of I3SLS has not yet been established theoretically, efforts are underway to establish statistical properties of this estimator. Anticipating further development, this procedure was employed and (converged) estimates presented for future interpretation and evaluation.

The structural equations were fit by the alternative estimates using U. S. annual time series data for 1936-41, 1949-63, secondary data obtained primarily from the records of federal government departments and agencies were used. In general, the 3SLS(2SLS) coefficient estimates appeared economically plausible and the coefficient estimates were generally statistically significant (i.e., estimated coefficient to standard error ratios of two or more were obtained). The 3SLS(2SLS) standard errors were generally smaller than the standard errors for the alternative estimation methods. No rigorous procedure was developed to ascertain the advantages of a given estimator, but the empirical results for 3SLS(2SLS) were generally plausible and different from estimates based on single equation methods. Typically, the 2SLS, UNK, and OLS methods yielded coefficient estimates which were comparable in magnitude; but LISE results were often erratic. As noted briefly above, I3SLS converged estimates were presented; it turned out that the Iterative-3SLS procedure produced (to at least 6 digits) the same set of estimates regardless of whether the procedure was started with 2SLS, UNK, or LISE estimates. Also, the I3SLS results were the least different from the 3SLS(2SLS) estimates, which is related to the fact that 3SLS(UNK) and 3SLS(LISE) estimates generally were similar to the 3SLS(2SLS) results. (We note that Zellner and Theil have recommended that 2SLS estimates be used as starting estimates for the 3SLS procedure; so our results tend to support their recommendation.)

Theoretically, the 3SLS estimator has preferred asymptotic properties, relative to the alternative estimation methods employed herein. Due to this, and due to the nature of the empirical results as described above, the 3SLS(2SLS) coefficient estimates were interpreted in the greatest detail. Sufficient data have been included either in summary tables or in the appendices so that corresponding derived estimates (e.g., elasticities) can be obtained for the other estimators.

Coefficient estimates from the alternative estimators, corresponding standard errors, and some additional comparative statistics (R^2's, k-values, and Durbin-Watson statistics) were summarized and discussed equation by equation in Chapter IV. Also, two statistical tests regarding the identifiability of the structural relations (based on LISE test statistics), were summarized (see Tables 4.9-4.11).

Several extensions were included in order to further evaluate the model in this study, particularly the cattle-beef sector equations. First, in order to more fully investigate the long run response of the producer-segment of our model to specified changes in farm product prices, especially the long run nature of beef cattle producers' slaughter supply responses, we explored a "reduced form" subset of our producer-segment endogenous variables. The presence of lagged endogenous variables in the system provided the model with some dynamic properties, which did in fact serve as a basis for generating a series of long run slaughter beef supply functions. For example, price elasticities of slaughter beef supply for 1, 3 and 5-year adjustment horizons were estimated as -.1381, + .1127, and + .3284, respectively (see Table 4.11, for a summary of the estimated results). With these results arising from the structural-model producer-segment, we regard the fitted structural slaughter beef supply equation as economically plausible.

Second, we further noted (and illustrated) the generally close fits of the estimated (by 3SLS(2SLS)) structural equations (when viewed as explicit functions of the normalizing variables). Also, corresponding residuals were presented and a brief summary evaluation made (see Figures 4.10 to 4.19 and following discussions).

Another (secondary) interest in this study was to explore the forecasting features of the estimated model. Since the structural model is complete, the reduced form is in itself a one-year forecasting mechanism. Besides the reduced form coefficient estimates presented in Appendix B, we explored how the model might be expected to perform over a number of periods by prescribing alternative sets of lagged endogenous and exogenous variable values; namely, the actual values for each period for the exogenous variables, but only initial (1936) values for the lagged endogenous. For each period afterwards, the previous period forecast endogenous variables (corresponding to lagged endogenous) were fed back into the system. Hence, our "forecasts" represented successive-period forecasts. In general, this exploration indicated that the reduced form equations may lack precision for any particular forecast period, but that typically the forecasts did follow the general time-path pattern of the actual series. Also, the 1964 (outside the sample period) one-period forecast estimates were derived (see Table 4.12).

Finally, some comparisons with related research results were made; first for retail beef demand price and income elasticities. Generally, the estimated price elasticities from this study are comparable with estimates from other studies; however, our income elasticities are usually higher than other estimates. This result was expected insofar as factors (e.g., population and possibly trend) were omitted from direct specification in the structural demand for beef at retail equation. Second, comparisons of estimated farm beef supply elasticities were made. (see Tables 4.13 and 4.14). The negative short run structural slaughter beef supply elasticity estimate from this study (ε(QBEEFP/PBEEFF) = - .137) is lower than some other estimates; however, this result seems plausible (given more than one production component and the nature of the beef cattle production process) and is not inconsistent with those studies where both slaughter and non-slaughter components of producer supplies (combined) were considered.

In conclusion, the main emphasis of this study was on underlying structural relationships within the cattle-beef sector of the U. S. economy. We regard the inclusion of the other livestock-meat sector relationships in our model as a means to more direct and meaningful consideration of interrelationships <u>between</u> the cattle-beef and other livestock-meat sectors. We consider the contributions of this report to be, first, the development of a structural form system of simultaneous equations that portrays the aggregative endogenous mechanisms and underlying characteristics of the cattle-beef and the other livestock-meat sectors; second, the application of alternative estimators with an apparent advantage of the simultaneous equations 3SLS(2SLS) "full-information" system estimation procedure for fitting this particular model; and finally, an indication of applications for which such a complete structural form fitted model may be used.

Like most studies of this kind, many additional applications and extensions would have preferably been included. Some further analyses would seem appropriate with respect to specifications of the structural relations if more suitable observable variables are found. Also, additional studies with less aggregative "other livestock" components may prove more meaningful, at least from the standpoint of the usefulness of empirical results pertaining thereto.[1] More sophisticated procedures for evaluating alternative estimators are needed. After further development with the structural form model, increased emphasis on the reduced form fitted relations would seem appropriate (although, modifications of the reduced form equations obtained in this study may be found useful). Further analyses based on postwar data (as more observations become available) seem desirable given changing aspects within the producer, marketing and consuming segments.

We regard this study as an example of one important method of approach to the study of economic relationships within the cattle-beef sector and between that sector and the rest of the economy, and we hope to have contributed to a better understanding of those relationships.

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[1]We recognize that "other livestock" (i.e., hogs, sheep and lambs, vealers, chickens, and turkeys) in this study is a heterogenous grouping. While we think total aggregate effects of this "sector" have been captured in the system here, we have no comparative basis for determining whether a less aggregative system may be preferred.

APPENDICES

APPENDIX A

Additional Equations

Several equation specifications alternative to those presented in the text of this report were investigated. Tabled in APPENDIX A are some of these fitted (by 2SLS) equations and related statistics. In all cases standard errors appear immediately below the coefficient estimates. Variables other than those presented in the text are defined below (means for the sample period are in parentheses).

Variables

TIME (16.0)	:	A linear TIME trend, t = 1 for 1936, t = 2 for 1937, t = 3 for 1937,...
POPN (155.74)	:	POPulatioN eating out of civilian food supplies (July 1), millions
PCDISPY (1619.8)	:	Per Capita DISPosable income(Y), (DISPY/POPN)* 1000; dollars per capita
AHRWAGE (85.07)	:	Average HouRly WAGE index for marketing farm food products, deflated with CPI, 1957-59 = 100
ULABORC (96.22)	:	Unit LABOR index for marketing farm food products, 1957-59 = 100
AVAILFG1 (123.73)	:	AVAILable Feed Grains (lagged crop year production plus non-government carryover); million tons
PFEEDID (90.62)	:	Price of FEED InDex, deflated with PPFI; 1957-59 = 100
PBEEFFL (19.57)	:	Price of BEEF cattle (average) at the Farm Lagged 1 year (i.e., PBEEFF lagged), deflated with PPFI; dollars per cwt.
EPBEEF1 (19.12)	:	Expected Price of BEEF cattle for a 1-year horizon (i.e., a current period price expectation variable), deflated with PPFI, dollars per cwt.

Table A.1

ALTERNATIVE SPECIFICATIONS OF THE DEMAND FOR BEEF
AT RETAIL: 2SLS COEFFICIENT ESTIMATES AND RELATED STATISTICS

PBEEFT	QBEEFC	POMEATR	CONSTANT	DISPY	TIME	POPN	PC DISPY	R^2 D.W.
-1.0	-.00737	.3253	42.39	.3578	.2692			.9363
	.00096	.1437	17.17	.1245	.9623			1.16
-1.0	-.00840	.4932	-68.98	.1776		1.0524		.9755
	.00061	.0917	22.92	.0495		.2175		1.54
-1.0	-.00914	.5928	-119.56	.3087	-1.5021	1.3302		.9833
	.00058	.0864	26.99	.0664	.5788	.2098		2.16
-1.0	-.00816	.4815	-114.05			1.4311	.0185	.9706
	.00065	.1077	14.50			.1536	.0065	1.43

Table A.2

ALTERNATIVE SPECIFICATIONS OF MARKETING IN THE
CATTLE-BEEF SECTOR: 2SLS COEFFICIENT ESTIMATES AND RELATED STATISTICS

PBEEFF	PBEEFR	QBEEFP	CONSTANT	DISPY	CMKTGM	TIME	AHRWAGE	ULABORC	R^2 D.W.
-1.0	.0779	-.00323	25.27	.1138	-.3518	.2432			.9733
	.0585	.00060	5.54	.0281	.1359	.2566			1.80
-1.0	.0260	-.00415	14.35	.1273			.2028		.9546
	.0618	.00069	3.82	.0325			.1463		2.12
-1.0	-.0856	-.00482	11.83	.1976				.1815	.9533
	.1201	.00100	4.36	.0414				.1199	2.47

Table A.3

ALTERNATIVE SPECIFICATIONS OF SLAUGHTER SUPPLY OF
BEEF CATTLE: 2SLS (AND OLS) COEFFICIENT ESTIMATES AND RELATED STATISTICS

QBEEFP	PBEEFF	CONSTANT	IBEEFF1	IBEEFNF1	PROTEIN	TIME	AVAILFG1	PFEEDID	R^2 D.W.
-1.0	-242.19	10070.	.2090	-.0047	-7.417	346.5			.9924
	43.63	1595.	.1597	.0453	18.447	94.1			1.86
-1.0	-253.58	10387.	.2391	-.0261		394.7	-4.340		.9924
	35.03	2080.	.1865	.0498		87.3	10.998		1.88
-1.0	-275.79	9574.	.2538	-.0442		419.9		9.395	.9924
	47.95	1629.	.1879	.0598		95.5		15.931	2.10

QBEEFP	CONSTANT	IBEEFF1	IBEEFNF1	PROTEIN	PBEEFFL	EPBEEF1	R^2 D.W.
-1.0	5787.2	.4544	.1676	-36.96	-109.73		.9869
(OLS)	1761.6	.1846	.0251	16.52	23.33		1.33
-1.0	6362.7	.4893	.1593	-38.32		-127.52	.9869
(OLS)	1773.3	.1848	.0249	16.48		27.10	1.09

Table A.4

ALTERNATIVE SPECIFICATIONS OF INVENTORY DEMAND FOR BEEF
CATTLE RETAINED FOR FEEDING: 2SLS COEFFICIENT ESTIMATES AND RELATED STATISTICS

IBEEFF2	PBEEFF	POMEATF	CONSTANT	IBEEFF1	TIME	IBEEFNF1	PROTEIN	R^2 D.W.
-1.0	27.38	-73.36	1957.2	.7597	34.19			.9722
	24.38	38.57	1295.9	.1831	31.93			2.68
-1.0	47.76	-88.11	1457.9	.6713		.0310		.9758
	20.02	39.19	1014.7	.1786		.0187		2.62
-1.0	73.11	-104.76	689.2	.6780		.0630	-55.68	.9779
	37.38	41.06	1453.8	.1770		.0411	65.66	2.75

Table A.5

ALTERNATIVE SPECIFICATIONS OF INVENTORY DEMAND FOR BEEF
CATTLE NOT-RETAINED FOR FEEDING: 2SLS COEFFICIENT ESTIMATES AND RELATED STATISTICS

IBEEFNF2	PBEEFF	CONSTANT	IBEEFNF1	ARANGECI	TIME	R^2 D.W.
-1.0	566.91	-25105.3	1.3278	105.06	-469.8	.9951
	107.35	7451.1	.1405	53.95	214.9	1.17

Table A.6

ALTERNATIVE SPECIFICATIONS OF DEMAND FOR OTHER MEAT
AT RETAIL: 2SLS COEFFICIENT ESTIMATES AND RELATED STATISTICS

POMEATR	PBEEFR	QOMEATC	CONSTANT	DISPY	TIME	POPN	R^2 D.W.
-1.0	.5480	-.00942	115.9	.1182	1.683		.8615
	.0919	.00155	18.7	.1035	.900		1.54
-1.0	.5807	-.00835	125.8	.3646		-.4265	.8539
	.0903	.00160	28.5	.0834		.2864	1.97
	.4357	-.00859	178.3	.1915	2.130	-.6015	.9220
	.0832	.00120	27.9	.0850	.720	.2232	2.23

Table A.7

ALTERNATIVE SPECIFICATIONS OF MARKETING IN THE OTHER LIVESTOCK-
MEAT SECTOR: 2SLS COEFFICIENT ESTIMATES AND RELATED STATISTICS

POMEATF	POMEATR	QOMEATP	CONSTANT	DISPY	CMKTGM	TIME	AHRWAGE	ULABORC	R^2 D.W.
-1.0	.3959	-.00068	8.74	2.081	-.492	-.617			.9731
	.0294	.00041	7.46	.023	.130	.219			2.13
-1.0	.3683	-.00031	12.04	.0601			-.2845		.9425
	.0340	.00040	4.70	.0355			.1218		2.09
-1.0	.5313	.00006	14.72	.0050				-.2770	.9397
	.0937	.00040	5.94	.0177				.1406	2.07

Table A.8

ALTERNATIVE SPECIFICATIONS OF SUPPLY OF OTHER LIVESTOCK:
2SLS (AND OLS) COEFFICIENT ESTIMATES AND RELATED STATISTICS

QOMEATP	POMEATF	CONSTANT	PFEEDID	QOMEATPL	TIME	POMEATFL	R^2 D.W.
-1.0	-86.13	9377.0	3.685	.3195	219.26		.9758
	99.57	2713.2	28.618	.1984	77.49		1.71
-1.0	-76.36	9956.1	9.092	.2437	248.70	-29.82	.9755
	116.62	3433.2	27.471	.3006	116.28	91.69	1.66

QOMEATP	CONSTANT	POMEATFL	PFEEDIDL	QOMEATPL	TIME	R^2 D.W.
-1.0	11805.3	96.15	-55.65	.4124	162.15	.9779
(OLS)	2826.4	80.66	23.46	.2332	88.25	2.26

APPENDIX B

3SLS(2SLS) and I3SLS Reduced Form Fitted Equations (and R^2's)

The reduced form coefficients (denoted as Π in the text, where Π is derived from the structural form parameter estimates) for 3SLS(2SLS) and I3SLS procedures are presented in this APPENDIX. Also, we report a coefficient of determination, R^2, for each of these equations. The following table contains these estimates. (Note that reduced form equations for QBEEFC and QOMEATC differ from these for QBEEFP and QOMEATP only by a predetermined variable, i.e., NBIMPORT and NOMIMPORT, respectively. Thus, these equations are not included here.)

Table B.1

3SLS(2SLS) AND I3SLS
REDUCED FORM FITTED EQUATIONS (AND R^2's)

Equation	Dependent Variable		Estimation Method	CONSTANT	DISPY	CMKTGM	IBEEFF1	IBEEFNF1	PPROTEIN
1.	PBEEFR	a)	3SLS(2SLS)	-2.8337	0.94287	-0.46419	-0.00988	-0.00197	0.46721
		b)	I3SLS	59.4965	0.85412	-0.42717	-0.010136	-0.00217	-0.29082
2.	PBEEFF	a)	3SLS(2SLS)	7.381697	0.30920	-0.59973	-0.00416	-0.000831	0.19667
		b)	I3SLS	36.7404	0.28625	-0.68313	-0.004138	-0.00088	-0.11874
3.	QBEEFP	a)	3SLS(2SLS)	4507.995	-24.515	47.5502	1.0124	0.20229	-47.8591
		b)	I3SLS	-3387.33	-18.7977	44.8597	1.06448	0.2284	30.54089
4.	IBEEFF2	a)	3SLS(2SLS)	501.26945	- 5.8798	9.99611	0.92871	-0.00763	1.8064
		b)	I3SLS	1598.447	- 4.4368	1.80159	0.92336	-0.009897	- 1.3234
5.	IBEEFNF2	a)	3SLS(2SLS)	-9917.56	110.8886	-215.0797	-1.4921	0.72819	70.5327
		b)	I3SLS	2500.678	103.65787	-247.3738	-1.4987	0.704409	-42.99879
6.	POMEATR	a)	3SLS(2SLS)	-2.76718	0.87394	-0.30339	-0.006459	-0.00129	0.30536
		b)	I3SLS	11.55405	0.80225	-0.28016	-0.006647	-0.0014	-0.190735
7.	POMEATF	a)	3SLS(2SLS)	10.1287	0.3478	-0.64608	-0.0023	-0.0004599	0.10880
		b)	I3SLS	10.1867	0.31354	-0.57104	-0.00230	-0.000495	-0.06625
8.	QOMEATP	a)	3SLS(2SLS)	9933.0957	-0.0000	0.0000	0.0000	0.0000	0.0000
		b)	I3SLS	13237.94	0.0000	0.0000	0.0000	0.0000	0.0000

Table B.1 (con't)

	ARANGECI	POMEATF2	PFEEDIDL	QOMEATPL	NOMIMPORT	NBIMPORT	R^2
1.a)	0.0000	-1.45497	0.62291	-0.005229	-0.00646	-0.010995	0.3056
b)	0.0000	-1.48146	0.725067	-0.0045	0.00601	-0.01092	0.0751
2.a)	0.0000	-0.21077	0.09023	-0.000757	-0.000937	-0.00159	0.5247
b)	0.0000	-0.30368	0.14863	-0.0009229	-0.00123	-0.0022	0.2723
3.a)	0.0000	16.7116	-7.15467	0.060064	0.074309	0.12628	0.9602
b)	0.0000	19.9423	0.06061	-9.76032	0.08095	0.14703	0.9361
4.a)	0.0000	56.75697	-24.2991	0.20399	0.188375	0.0682129	0.9753
b)	0.0000	54.6359	-26.7402	0.16605	0.15843	0.03648	0.9744
5.a)	77.66006	-75.5901	32.3621	-0.27168	-0.3361	-0.5712	0.9823
b)	54.5574	-109.9699	53.82219	-0.33423	-0.44640	-0.81078	0.9757
6.a)	0.0000	-2.84765	1.21915	-0.01023	-0.01266	-0.007086	-0.1889
b)	0.0000	-2.95041	1.4440	-0.008967	-0.011976	-0.00716	-0.5434
7.a)	0.0000	-1.30639	0.5595	-0.00469	-0.00451	-0.00256	0.2407
b)	0.0000	-1.33959	0.65563	-0.00061671	-0.00416	-0.002488	0.0241
8.a)	0.0000	224.8937	-96.28287	0.808297	0.0000	0.0000	0.9721
b)	0.0000	246.3465	-120.5685	0.74872	0.0000	0.0000	0.9651

APPENDIX C

Data Sources and Data

Data Sources

The sources of data for each variable used in this study (both in the text and in Appendix A) are indicated here. Two major sources are Agricultural Statistics, annual series; and Livestock and Meat Statistics, periodic series with annual supplements. For convenience, we let Statistics refer generally to Agricultural Statistics (1957, 1962, 1964), USDA, Washington: U.S. Government Printing Office. Since summary tables of time series data have been included in these particular publications (except for 1964, which was a source for 1963 data), we note table numbers for particular variables that correspond with the 1962 publication. Also, we let Livestock and Meat Statistics refer generally refer to:

Livestock and Meat Statistics, 1957, USDA, Statistical Bulletin No. 230, Washington: U. S. Government Printing Office, July 1958;

Livestock and Meat Statistics, 1962, USDA, Statistical Bulletin No. 333, Washington: U. S. Government Printing Office, July 1963; and

Livestock and Meat Statistics, Supplement for 1963 (and 1964) to Statistical Bulletin No. 333, USDA, Washington: U. S. Government Printing Office.

We will note table numbers as they appeared in the 1962 publication.

PBEEFR	Retail beef price per pound (estimated weighted average price of retail cuts from choice grade carcass), annual, cents, Livestock and Meat Statics (Table 199). (Non-deflated)
QBEEFC	Total civilian consumption of beef, annual, million pounds, Livestock and Meat Statistics (Table 210).
POMEATR	Weighted average retail price per pound (weights were QOMEATC components divided by total QOMEATC), cents; PORK: Retail pork price per pound (estimated weighted average price of retail cuts), annuals, cents, Livestocks and Meat Statistics, (Table 200); VEAL: average annual retail price (estimated as 80 percent of veal cutlet price), selected cities, Monthly Labor Review, series; LAMB: Retail lamb price per pound (estimated weighted average price of retail cuts from choice grade carcass), annual, cents, Livestock and Meat Statistics (Table 201); CHICKEN (and TURKEY): Average retail price for chickens, U.S., Monthly Labor Review, annual, averages, series and Poultry and Egg Situation, November 1964, (Table 8). (Non-deflated), liveweight, cents, U.S., Agricultural Statistics (Table 616). Non-deflated)
PBEEFF (and PBEEFFL)	Average price of beef cattle received by farmers per 100 pounds, 48 states, dollars, Livestock and Meat Statistics (Table 180). (Non-deflated)
QBEEFP	Total beef production (slaughter), 48 states, million pounds, Livestock and Meat Statistics, (Table 113).
IBEEFF2 (and IBEEFF1)	Cattle and calves on feed, 26 states, January 1, 1000 head, Livestock and Meat Statistics (Table 23).
POMEATF (and POMEATFL)	Weighted average price (dollars) per cwt. (weights were QOMEATP quantity components divided by total QOMEATP); HOGS: Weighted average price received by farmers, Livestock and Meat Statistics (Table 182); VEAL: Average vealer price, choice grade, St. Louis National Stock Yards, Livestock

and Meat Statistics (Table 164); SHEEP and LAMBS: Average price (for lambs) received by farmers, per cwt., 48 states, *Livestock and Meat Statistics* (Table 184); CHICKEN: Average price of commercial broilers, U.S., cents/16, *Agricultural Statistics* (Table 603; TURKEY: Average price per pound and liveweight cents, *Agricultural Statistics* (Table 616). (Non-deflated)

IBEEFNF2 (and IBEEFNF1) — Total "other" (not kept for milk) cattle and calves (minus IBEEFF2), United States, 1000 head, *Livestock and Meat Statistics*, (Table 7)

QOMEATC — Total civilian consumption of pork (Table 212), plus veal (Table 211), plus lamb and mutton (Table 213), in *Livestock and Meat Statistics*, plus turkey, ready to cook basis, million pounds, Agricultural Statistics (Table 618).

QOMEATP (and QOMEATPL) — Total production of pork, veal, lamb and mutton, chicken and turkey, same sources as for QOMEATC.

DISPY — Disposable personal income, billion dollars, *Agricultural Statistics* (Table 629). (Non-deflated)

CMKTGM — Total meat marketing bill divided by total red meat civilian consumption: *Marketing Bill* for meat products, billions of dollars, annual, *Agricultural Statistics* (Table 679). All meat total U.S. civilian consumption (includes beef, veal, lamb and mutton), and pork, excluding lard, *Agricultural Statistics* (Table 533). This series was transformed as defined in the text to arrive at the actual variable used.

PPROTEIN — Price of protein feed in dollars per 1000 pound TPN, calendar year. These data were taken from Feltner, R. L.: "Alternative Models of the Feed Livestock Economy," Ph.D. Thesis, North Carolina State, 1965. A detailed discussion of this variable is in Hildreth, C. and Farrett, F. G.: *A Statistical Study of Livestock Production and Marketing*, New York: John Wiley and Sons, 1955, pp. 43-45, (The principal kinds of feeds included are soybean, cottonseed, linseed, and copia cakes and meal; dried grains,

	peanut cake and meal, tankage, fish meal and other by-products). (Non-deflated)
ARANGECI	Average (of August, September and October) range (first of month) condition, percent of normal, U.S. Agricultural Statistics (Table 404).
PFEEDID (PFEEDIDL)	Price paid (index numbers) by farmers for feed, U.S., 1957-59 = 100, Agricultural Prices, SRS, USDA, May 1962, p. 49. (Non-deflated).
NOMIMPORT	QOMEATC-QOMEATP, sources as defined.
NBIMPORT	QBEEFC-QBEEFP, sources as defined.
POPN	Population, number of people eating from civilian food supplies, July 1, millions, Agricultural Statistics (Table 794).
PCDISPY	Per capita disposable income, calculated as DISPY divided by POPN, note sources above. (Non-deflated)
AHRWAGE	Average hourly earnings for marketing farm food products, Index numbers 1957-59 = 100, U.S. Marketing and Transportation Situation, MTS-150, USDA, August 1963. (MTS-154, 1964) (Table 7). (Non-deflated)
ULABORC	Unit labor costs for marketing farm food products, Index numbers 1957-59 = 100, Marketing and Transportation Situation, MTS-150, USDA, August 1963 (also MTS-154, 1964, p. 15) (Table 7). (Non-deflated)
AVAILFG1	Total feed grain production plus other (non-government) carry over, U.S. marketing years (includes October-September year for corn and sorgum grain, July-June year for oats and barley), applies to production up to current year September or June end of marketing year, million tons, Grain and Feed Statistics, USDA, ERS, Statistical Bulletin No. 159, Supplement for 1964, March 1965.
EPBEEFL	Beef price expectations (average price received by farmers), dollars per cwt., in Lerohl, Milbourn: Expected Prices for U.S. Agricultural Commodities, 1917-62, Michigan State University,

Ph.D. Thesis, 1965. An estimate for 1963 was made following Lerohl's procedures (Non-deflated)

CPI5759 Consumer Prices, all items (U.S. Dept. of Labor), index number 1957-59 = 100, Agricultural Statistics (Table 629).

PPFI5759 Prices paid by farmers, total including interest, taxes and wages, index numbers 1957-59 = 100, Agricultural Statistics (Table 629).

Data

The actual data which were used in this study are presented in the following table. (Note that all monetary variables are presented in their deflated forms.)

Table C.1

DATA USED IN THIS STUDY
(EXCLUDES DATA FOR VARIABLES INTRODUCED IN APPENDIX A)

	PBEEFR	QBEEFC	POMEATR	PBEEFF	QBEEFP	IBEEFF2	POMEATF	IBEEFMF2	QOMEATC
	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
Year	cents per pound	mil. pounds	cents per pound	$/cwt	mil. pounds	1000 head	$/cwt	1000 head	mil. pounds
1936	59.21	7742	62.82	13.85	7358	2759	24.72	28486	11018
1937	65.00	7107	64.16	15.56	6798	3336	24.13	27139	11192
1938	58.45	7058	58.00	15.57	6908	3303	21.88	27100	11383
1939	60.95	7159	54.40	17.00	7011	3633	19.03	28254	12501
1940	60.45	7257	49.02	18.00	7175	4065	17.43	30307	13802
1941	61.40	8021	56.10	19.60	8082	4185	23.84	33003	13332
1949	82.41	9439	71.45	23.02	9439	4390	24.77	38118	15289
1950	89.98	9529	70.13	26.48	9534	4534	24.03	42151	15901
1951	97.46	8472	69.06	29.59	8837	4961	24.23	47876	16323
1952	93.30	9548	66.47	24.80	9650	5762	21.94	52558	16859
1953	74.14	12113	67.58	17.16	12407	5370	24.26	54148	16285
1954	73.18	12743	68.11	16.84	12963	5795	23.05	55455	16340
1955	72.35	13313	62.31	16.60	13569	5929	19.59	55762	17391
1956	69.69	14121	57.68	15.68	14462	6122	17.93	53447	18331
1957	72.04	14242	60.54	17.55	14202	5898	19.32	53316	17773
1958	84.37	13786	61.33	21.90	13330	6601	20.03	56013	18037
1959	81.58	14202	54.96	22.16	13580	7173	15.70	58882	19747
1960	78.56	15121	54.58	20.00	14727	7645	16.65	59913	19607
1961	76.01	15873	53.02	19.61	15298	7865	16.02	62587	19991
1962	78.18	16298	53.73	20.29	15296	8941	16.06	66144	20437
1963	75.91	17658	51.57	18.77	16423	8988	14.96	69846	20998
1964	71.97	18984	49.91	16.82	18424	9483	14.71	71000	21361
MEAN	74.32	11466.76	60.43	19.53	11288.05	5583.57	20.46	47648.19	16311.29

Table C.1 (con't)

Year	QOHEATP Y_{10} mil. pounds	DISPY X_1 bil. dollars	CMKTGH X_2 cents per pound	IBEEFF1 X_3 1000 head	IBEEFNF1 X_4 1000 head	PPROTEIN X_5 $/1000-# ton	ARANGECI X_6 % of normal	POMEATFL X_7 $/cwt
1936	11495	137.06	24.84	3202	29193	85.02	72.33	23.67
1937	10901	142.00	25.20	2759	28486	85.56	76.33	24.72
1938	11524	133.81	23.01	3336	27139	76.28	83.66	24.13
1939	12715	145.45	21.90	3303	27100	82.00	73.00	21.88
1940	14178	155.94	20.70	3633	28254	77.98	80.66	19.03
1941	13958	181.29	18.52	4065	30307	87.38	92.33	17.43
1949	15783	228.55	22.53	4540	37020	73.60	81.66	29.04
1950	16330	247.85	22.55	4390	38118	68.31	84.66	24.77
1951	17197	251.38	22.21	4534	42151	66.67	78.66	24.03
1952	17582	258.06	23.68	4961	47876	77.49	74.66	24.23
1953	16615	270.92	29.93	5762	52558	63.13	75.33	21.94
1954	16864	274.47	23.40	5370	54148	71.28	71.00	24.26
1955	17716	294.11	25.19	5795	55455	60.85	78.33	23.05
1956	18747	309.29	24.92	5929	55762	55.44	66.33	19.59
1957	18095	315.10	25.20	6122	53447	51.33	82.33	17.93
1958	18462	315.70	25.22	5898	53316	54.22	83.00	19.32
1959	20092	332.12	25.81	6601	56013	52.76	79.00	20.03
1960	19871	339.38	25.41	7173	58882	48.61	78.66	15.70
1961	20622	349.71	25.43	7645	59915	53.41	78.66	16.65
1962	20799	364.71	25.05	7865	62587	54.78	81.33	16.02
1963	21549	377.32	24.74	8941	66144	54.25	77.33	16.06
1964	21934	399.44	24.24	9433	69671	53.27	75.33	14.99
MEAN	16718.81	258.30	23.78	5324.95	45898.62	66.68	78.54	21.12

Table C.1 (con't)

Year	PFEEDIDL X_8 1957-59= 100	QOMEATP X_9 mil. pounds	NOMIMPORT X_{10} mil. pounds	NBIMPORT X_{11} mil. pounds	CPI5759 1957-59= 100	PPFI5759 1957-59= 100
1936	126.19	9687	-477	384	48.3	42.0
1937	110.57	11495	291	309	50.0	45.0
1938	137.78	10901	-141	150	49.1	42.0
1939	111.90	11524	-241	148	48.4	42.0
1940	111.90	12715	-376	82	48.8	42.0
1941	119.05	14178	-626	- 61	51.3	45.0
1949	140.45	15208	-494	0	83.0	86.0
1950	119.77	15783	-429	- 5	83.8	88.0
1951	119.32	16330	-874	-365	90.5	97.0
1952	121.65	17197	-723	-102	92.5	98.0
1953	128.57	17582	-330	-294	93.2	95.0
1954	120.00	16615	-524	-220	93.6	95.0
1955	118.95	16864	-325	-256	93.3	94.0
1956	112.77	17716	-416	-341	94.7	95.0
1957	108.42	18747	-322	40	98.0	98.0
1958	103.06	18095	-425	456	100.7	100.0
1959	99.00	18462	-345	622	101.5	102.0
1960	98.04	20092	-264	394	103.1	102.0
1961	96.08	19871	-631	575	104.2	103.0
1962	95.15	20622	-362	1002	105.4	105.0
1963	95.24	20799	-551	1235	106.7	106.0
1964	96.26	21555	-573	560	108.1	107.1
MEAN	114.96	16213.48	-407.52	178.71	82.86	82.0

APPENDIX D

Simple Correlation Coefficients
Between Pairs of Variables

The simple correlation coefficients for all the endogenous and predetermined variables in this study (except variables introduced in Appendix A) are presented in Table D.1 below.

Table D.1

MATRIX (TRIANGULAR) OF THE SIMPLE CORRELATION
COEFFICIENTS OF DATA USED IN THE TEXT OF THIS DISSERTATION

	PBEEFR	QBEEFC	POMEATR	PBEEFF	QBEEFP	IBEEFF2	POMEATF	IBEEFNF2	QOMEATC	QOMEATP	DISPY
PBEEFR	1.0000										
QBEEFC	0.3019	1.0000									
POMEATR	0.4642	-0.3031	1.0000								
PBEEFF	0.8811	-0.0004	0.3441	1.0000							
QBEEFP	0.3264	.9936	-0.2437	0.0097	1.0000						
IBEEFF2	0.9439	0.9439	-0.3736	0.1964	0.9247	1.0000					
POMEATF	0.0367	- .6924	0.8260	0.1212	-0.6520	-0.7449	1.0000				
IBEEFNF2	0.5427	0.9424	-0.1356	0.2370	0.9496	0.9518	-0.5845	1.0000			
QOMEATC	0.5619	0.9298	-0.2421	0.3827	0.9318	0.9621	-0.6835	0.9655	1.000		
QOMEATP	0.5843	0.9153	-0.2250	0.3567	0.9193	0.9537	-0.6617	0.9637	0.9977	1.0000	
DISPY	0.5441	.9593	-0.1654	0.2664	0.9644	0.9537	-0.6159	0.9807	0.9860	0.9810	1.0000
CMKTGM	0.6512	0.6512	-0.0446	-0.1992	0.6358	0.5291	-0.4159	0.5757	0.5121	0.4770	0.5789
IBEEFF1	0.9701	0.9701	-0.3428	0.1271	0.9554	0.9779	-0.7107	0.9529	-0.0235	-0.0	0.9592
IBEEFNF1	0.4610	0.9664	-0.1503	0.1217	0.9768	0.9385	-0.5987	0.9897	0.9496	0.9422	0.9760
PPROTEIN	-0.9042	-0.9042	0.2370	-0.1640	-0.9119	-0.8476	0.6673	-0.8678	-0.9035	-0.8872	-0.9177
ARANGECI	-0.1249	-0.1249	-0.1005	0.3454	-0.1514	0.0720	0.0912	-0.1387	-0.0510	-0.0447	-0.0615
POMEATFL	.1504	-0.6350	0.7940	0.1532	-0.6003	-0.6701	0.7711	-0.5214	-0.5749	-0.5637	-0.5509
PFEEDIDL	-0.7466	-0.7466	0.6772	-0.1093	-0.7081	-0.8129	0.8606	-0.6944	-0.7642	-0.7557	-0.7239
QOMEATPL	0.9149	0.9149	-0.1518	0.3362	0.9246	0.9439	-0.5816	0.9643	0.9776	0.9750	0.9808
NOMIMPORT	-0.1620	-0.1620	-0.1387	-0.5740	-0.1895	-0.2580	-0.0335	-0.3500	-0.3556	-0.4186	-0.3133
NBIMPORT	0.4806	0.4806	-0.5918	-0.0786	0.3784	0.5559	-0.6126	0.3503	0.3853	0.3638	0.3737

	CMKTGM	IBEEFF1	IBEEFNF1	PPROTEIN	ARANGECI	POMEATFL	PFEEDIDL	QOMEATPL	NOMIMPORT	NBIMPORT
CMKTGM	1.0000									
IBEEFF1	0.5400	1.0000								
IBEEFNF1	0.6410	0.9501	1.0000							
PPROTEIN	-0.6554	-0.8715	-0.8862	1.0000						
ARANGECI	-0.4333	-0.0413	-0.2021	0.0562	1.0000					
POMEATFL	-0.1910	-0.6633	-0.5261	0.5614	-0.1717	1.0000				
PFEEDIDL	-0.3769	-0.7663	-0.6757	0.6986	-0.0096	0.8584	1.0000			
QOMEATPL	0.4677	0.9416	0.9473	-0.8798	0.0147	-0.5687	-0.7006	1.0000		
NOMIMPORT	0.2818	-0.2794	-0.2664	0.1268	-0.0657	0.0691	0.1801	-0.3440	1.0000	
NBIMPORT	0.4002	0.5318	0.3361	-0.3293	0.1519	-0.5432	-0.6209	0.3188	0.1442	1.0000

APPENDIX E

Additional 2SLS and 3SLS(2SLS) Structural Equation Estimates

The single equation results (2SLS, UNK, LISE) reported in the text (Chapter IV) for equations 1 and 6 were based on computations which did not include in the respective sets of predetermined variables (in the system but not in the equation) NBIMPORT in the case of equation 1 and NOMIMPORT in the case of equation 6. (All 3SLS computations, however, included all the predetermined variables in the system.) The 2SLS estimates for these two equations were recomputed including these respective variables, and the corresponding 3SLS(2SLS) estimates for all equations were also obtained. The results are summarized in this appendix, and the original estimates reported in the text are also given here for ease of comparison.

Table E.1

2SLS ESTIMATES OF EQUATION 1 WITH AND WITHOUT NBIMPORT IN THE SYSTEM, AND OF EQUATION 6 WITH AND WITHOUT NOMIMPORT

Equation		PBEEFR	QBEEFC	POMEATR	CONSTANT	DISPY
1	(a) with NBIMPORT	-1.0	-.00743	.3447	37.81	.3904
			.00090	.1344	9.26	.0376
	(b) without NBIMPORT	-1.0	-.00744	.3357	38.40	.3910
			.00090	.1348	9.29	.0376
		POMEATR	PBEEFR	QOMEATC	CONSTANT	DISPY
6	(a) with NOMIMPORT	-1.0	.6052	-.00892	88.44	.2810
			.0805	.00168	11.07	.0638
	(b) without NOMIMPORT	-1.0	.6419	-.00894	86.50	.2787
			.0872	.00172	11.38	.0650

Table E.2

3SLS(2SLS) ESTIMATES FOR EQUATIONS 1 TO 8:
WITH AND WITHOUT NBIMPORT IN THE SYSTEM FOR EQUATION 1;
AND WITH AND WITHOUT NOMIMPORT IN THE SYSTEM FOR EQUATION 6

Equation		PBEEFR	QBEEFC	POMEATR	CONSTANT	DISPY	
1	(a) with	-1.0	-.00679	.4684	29.14	.3669	
			.00077	.1090	7.56	.0323	
	(b) without	-1.0	-.00676	.4713	28.92	.3654	
			.00077	.1089	7.55	.0322	
		PBEEFF	PBEEFR	QBEEFP	CONSTANT	DISPY	CMKTGM
2	(a) with	-1.0	.1107	-.00302	21.42	.1306	-.4091
			.0336	.00038	2.24	.0171	.0846
	(b) without	-1.0	.1100	-.00304	21.38	.1311	-.4043
			.0336	.00038	2.24	.0171	.0846
		QBEEFP	PBEEFF	CONSTANT	IBEEFF1	IBEEFNF1	PPROTEIN
3	(a) with	-1.0	-79.993	5049.06	.6816	.1370	-31.77
			24.092	1438.87	.1502	.0203	12.21
	(b) without	-1.0	-79.286	5093.26	.6826	.1364	-32.21
			24.074	1432.29	.1497	.0203	12.14
		IBEEFF2	PBEEFF	POMEATF	CONSTANT	IBEEFF1	
4	(a) with	-1.0	36.607	-49.477	734.84	.9664	
			17.394	30.522	851.04	0.0599	
	(b) without	-1.0	36.475	-49.330	731.67	.9669	
			17.390	30.498	850.52	.0599	

Table E.2 (con't)

Equation			IBEEFNF2	PBEEFF	CONSTANT	IBEEFNF1	ARANGECI	
5	(a)	with	-1.0	358.83	-12477.7	1.0263	76.50	
				67.71	3416.2	.0186	43.15	
	(b)	without	-1.0	358.63	-12564.8	1.0263	77.66	
				67.72	3419.8	.0186	43.20	
			POMEATR	PBEEFR	QOMEATC	CONSTANT	DISPY	
6	(a)	with	-1.0	.6486	-.00848	83.43	.2601	
				.0676	.00134	8.94	.0507	
	(b)	without	-1.0	.6536	-.00843	82.86	.2577	
				.0686	.00135	9.02	.0511	
			POMEATF	POMEATR	QOMEATP	CONSTANT	DISPY	CMKTGM
7	(a)	with	-1.0	.3565	-.00131	24.22	.0369	-.5463
				.0248	.00036	5.00	.0153	0.1192
	(b)	without	-1.0	.3563	-.00130	24.00	.0364	-.5380
				.0247	.00036	4.98	.0153	.1185
			QOMEATP	CONSTANT	POMEATFL	PFEEDIDL	QOMEATPL	
8	(a)	with	-1.0	9902.5	224.14	-95.97	.8089	
				1819.9	52.10	16.05	.0452	
	(b)	without	-1.0	9933.1	224.89	-96.28	.8083	
				1810.1	51.85	15.94	.0451	

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