Evaluation of Alternative Market Organizations in a Simulated Livestock-Meat Economy

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SUMMARY

The economic effects of alternative forms of market organization can be studied by direct observation or by experimenting with a simulated economy. The experimental approach in the study of market behavior is a relatively new but important technique for the analysis of many policy issues in American agriculture.

Experimenting on a simulated system is not an analytical approach confined to academic issues; it has its counterpart, for example, in the engineering fields. Major engineering installations often are based on studies involving the use of models in simulated situations; the experimental results provide a basis for more accurately anticipating the actual performance of a dam, a bridge or a vehicle under different conditions. Similarly, simulation in economic research involves model building and manipulation that makes possible the telescoping of years of actual experience into a matter of minutes and a few dollars worth of computer time.

This report is concerned with the preparation of a model of the livestock-meat economy and a procedure for experimenting on the simulated economy under a variety of market conditions. To achieve the objectives of the study, however, several important steps are involved.

First, the critical variables and relationships that make up the livestock-meat economy must be identified; in this study, they are estimated by the method of least squares. Next, the variables and relations are organized into cause-effect sequences as a recursive system made up of a series of multiple-variable equations. A computer program was prepared to generate the time paths of the endogenous variables in the economic model. The results are then compared with corresponding reported values of the variables and are adjusted, when necessary, to yield a better explanation of the historical phenomena. Finally, the basic elements of the computer model—the variables and relations—are varied according to different sets of assumptions regarding the market behavior of businesses and households.

In this study, the experimental results, based on alternative sets of assumptions, are evaluated in the light of two basic policy issues and five different policy goals. The basic policy issues in marketing livestock and meat pertain to the level of market efficiency and the degree of governmental control. The specific policy objectives refer to (a) price and output stability, (b) reduction of marketing margins, (c) consumer choice, (d) foreign trade and (e) maintenance of effective competition. The market experiments are evaluated with reference to each of the five policy objectives. Thus, the policy issues and objectives are not a part of the simulated economy but a frame of reference in judging the social importance of certain changes in market organization and structure.

In this report, the simulation technique is viewed as an aid in policy formulation; it is an economical procedure for comparing alternatives in the design of appropriate combinations of social and private goals and the means for working toward them. Because simulation is not optimization, it requires continued interaction between the analysis of the experiments and the judgments of the experienced policy maker. Indeed, the most that can be expected of simulation is guidance rather than prescription in planning and policy formulation.

Besides the application of the simulation technique in policy formulation, this report includes estimates of a host of economic variables and relationships that make up the computer model of the livestock-meat economy. The logic of the model was to establish, first, the components of meat consumption, then to estimate the wholesale price and to relate the wholesale price to live-animal price. Changes in the live-animal prices account for changes in breeding stock which, subsequently, determine domestic livestock slaughter — the major component of meat consumption.

Different assumptions pertaining to marketing margins, trade controls and price stabilization were introduced into the computer model to simulate alternative patterns of price and output determination in the beef and pork sectors. The results of the market experiments always were compared with the results based on the historical market structures; namely, the variables and relationships of the 1955-64 period. Also, the experimental results were evaluated in the light of the selected policy objectives.

Three different margin relations—fixed, variable and semivariable margins—and three different levels of these relations were assumed in the marketing margin experiments. With variable margins, price and output fluctuations were reduced, and marketing margins were lower than under the fixed or semivariable strategy. Foreign trade was about the same under each of the margin assumptions.

Foreign trade restrictions tended to increase price and output variability at the live-animal and retail market levels; they also lowered per-capita consumption. The assumption of stabilizing the supply of meat available for consumption, however, resulted in a reduction in price and output fluctuations, an increase in live-animal prices and an increase in exports.

Three different levels of each of three types of margin relations also were assumed as a means of ascertaining the incidence of changes in the wholesale-to-retail margin. The results showed that a 25-percent, or 4-cent, change in the variable margin

relation was associated with approximately a 3-cent change in retail prices and a 1-cent change in wholesale and live-animal prices. The change in retailing margins also was about 4 cents. Corresponding changes in the fixed margin relation and the semi-variable margin relation resulted in essentially the same price changes as in the case of the variable margin assumption. Thus, the simulation technique yields answers to the question: "If a particular economic sector were to increase its charges by 'x' amount, who would pay the bill?" Both consumers and producers would, but in disproportionate amounts because of differences in their responses to price changes.

Finally, the simulation technique is offered as a means of forecasting future levels of important decision variables. To the extent that the underlying assumptions are valid, the estimates of future prices and outputs are useful guidelines in economic planning, either in business or in public affairs.

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by Wilbur R. Maki and Richard J. Crom[2]

Recent trends in marketing margins and primary market reorganization in the livestock-meat economy are of increasing concern to livestock producers, marketing agencies and consumers. These are issues of national importance; their outcome will be determined ultimately in the context of national forces affecting livestock and meat prices.

The livestock and meat marketing system, theoretically, has a function of translating consumer preferences and demands into appropriate price signals that can be followed by processors and producers in producing products consumers want at prices that will clear the markets. The range of consumer choice may be severely limited, however, because the existing product variety is confined to numerous brand names attached to an essentially identical product, while desirable quality differences may be lacking. Often it is difficult for the average consumer to differentiate either among competing brands or among essentially different meat products because of the high degree of knowledge required to sort the individual items according to quality and price.

At the primary market level of the livestock and meat marketing system, incomplete knowledge on the part of the livestock producer also may curtail the effectiveness of the pricing process. Product value differences, because of lack of objective grading procedures and standards, may not be adequately recognized, resulting in a price structure that does not reflect the aggregate consumer choices for different qualities of meat products. Without adequate price differentials, livestock producers lack incentives to improve quality through changes in breeding and feeding practices. Thus, inadequate information can be a crucial limiting factor in the functioning of the marketing system.

At the retail, wholesale and processing levels of the livestock-meat economy, the degree of market knowledge may be substantially superior to that at the consumer and producer level. Yet, inefficiencies

may persist because of uncertainties and risks that face individual business enterprises. In the meat-packing sector, for example, relatively low rates of return on investment may discourage investment in new facilities. In the case of some packing companies, however, persistently low investment returns may be the incentive for new capital expenditures to improve their competitive positions. Ultimately, excess plant capacity will discourage investment by reducing long-run earnings prospects. Thus, the businesses engaged in marketing and processing livestock and meat products also need better market information to keep new investment expenditures in line with slowly increasing market demands.

Finally, the primary livestock markets are affected materially by the trends in the livestock and meat marketing system. For example, the role of the public terminal market in the price-making process has long been a subject of controversy. The decline of the central market has been viewed with alarm because of its alleged importance in the pricing process. In any event, the trend toward increasing centralization of the communication function and decentralization of the transportation function in the livestock-meat economy could eliminate the public terminal market as a central point for the assembly of livestock. Thus, market analyses, particularly as they pertain to the price-making role of different types of markets, would be extremely useful in evaluating the implications for primary markets of recent marketing trends.

Of the many factors that determine livestock and meat prices, the most important, undoubtedly, is the aggregate supply of livestock. Livestock supplies, of course, are influenced by the level of market prices—not only current prices but also those in past periods. Thus, in a study of the livestock and meat marketing system, the temporal factor is extremely important.

Secular trends affect the level of yearly fluctuations, but the shift in level is small compared with the much larger year-to-year changes in prices and outputs associated with changes in current production and lagged prices. Similarly, the seasonal or annual variability in prices and output has only a minor effect on week-to-week changes, although the latter are influenced in part by the longer run price-

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making phenomena. Different factors must be considered, therefore, in accounting for market changes over varying time periods.

The information requirements for decision-making on the part of livestock producers and marketing agencies also will vary depending upon the relevant planning horizon. Capital expenditures planning, for example, requires long-range projections of market demands and new facilities, including estimates of trends in population, consumer incomes, livestock supplies, capital expenditures and new construction. In addition, year-to-year fluctuations about the long-run trends are important insofar as they affect short-term profit prospects. Employment scheduling in meat-packing plants, on the other hand, depends primarily upon estimates of the level of market supplies and the seasonal fluctuations in these supplies. Thus, both year-to-year and week-to-week changes would be important in production planning. Finally, sales planning (i.e., the preparation of sales quotas and the allocation of product to different market areas within the meat-packing industry) is based upon weekly price and production forecasts. Indeed, short-term information would be most relevant for decision making with reference to the sales-planning function in the meat-packing industry.

This report is focused on the intermediate time period for planning purposes; namely, the year or half year. Much of the data reported have been prepared on a 6-month basis so that the seasonal fluctuations in prices and output can be identified. In addition, the findings pertain largely to the marketing sector; hence, they are represented in terms of farm inventory fluctuations rather than as changes in farm production. Farm inventory fluctuations are used to account for changes in meat production. Thus, the sales response, rather than the production response, is the relevant market-planning concept.

To organize the vast amount of data collected on a semiannual basis, a computer model of the livestock-meat economy, specifically the beef and pork sectors, was prepared. The availability of a computer program in Fortran language makes possible the use of the model for market experimentation. The effects of changes in selected market relationships and variables can be traced throughout the livestock-meat economy over an extended time period. The simulation model is presented, therefore, as a technique for formulating and evaluating market policy with reference to the livestock-meat economy.

Objectives of Study

The primary objective of this study has been to prepare a computer model that simulates the aggregate pricing and production processes in the livestock-meat economy of the United States over the historical period since 1955 and over a projection period to 1975. In addition, the model is used to prepare estimates of prices and outputs under different assumptions regarding both market relationships and market variables.

The objectives of the study have been carried out in six major stages as follows:

1. Specification of an economic model of the livestock-meat economy;

2. Estimation of the specified economic relations by using time-series data for the United States and selected regions over 1949-61;

3. Validation of the economic model by comparing the forecasts obtained with reported data;

4. Revision of the economic model on the basis of information obtained in the first three stages;

5. Experimentation on a simulated livestock-meat economy by using alternative economic assumptions;

6. Evaluation of simulation runs with reference to selected economic performance dimensions.

In summary, time-series data for selected markets are used in fitting an economic model of the beef and pork sectors of American agriculture. The economic model provides for the interaction of supply and demand components through the use of a Fortran program prepared specifically for generating selected price and production variables on a semiannual basis under alternative market assumptions. Thus, the computer program facilitates the evaluation of price and output projections. The experiments on the model, however, represent more than market projections of the livestock-meat economy; they also provide a basis for ascertaining the different price and production implications of alternative market strategies.

Comparisons among the simulation runs (i.e., the experiments performed on the computer model) provide a basis for further investigation of those facets of the livestock-meat economy that appear to be limiting factors in the improvement of over-all industry and market performance. In this sense, the computer simulations of the livestock-meat economy serve as partial substitutes for actual observations of economic variables obtained over several years.

This study is concerned, therefore, with the measurement and evaluation of the aggregate effects of alternative market strategies. It does not attempt to describe the decision strategies of individual economic units, nor does it focus on the testing of specific hypotheses pertaining to price and output responses of decision-makers in the livestock-meat economy. Rather, the study attempts to bring together a host of variables and relationships that can be used to describe the over-all market performance of the beef and pork sectors of the agricultural economy in the United States. The organization of the variables and their relationships into a comprehensive system of equations is viewed as one of the major contributions of this study.

Specified market conditions are associated with

particular strategies or combinations of strategies used by different groups of decision units that make up the livestock-meat economy. It is not an essential condition, however, for this study to relate precisely the micro-economic content of the macro-economic time-series performance dimensions. But it is useful to associate the specified market conditions with the activities of producing and consuming units. Thus, the price and production effects of alternative market strategies can be viewed in the context of the market conditions assumed in the alternative formulations of the basic economic model. To illustrate the applications of the model in policy planning, some major policy issues are examined as background to the discussion of specific variables and relationships that make up the economic model.

Stabilizing price and output cycles

From the producer standpoint, stabilization of cattle and hog production cycles has been presented as a desirable policy objective because of the opportunity offered for more efficient production practices (29). The plant and equipment needed for breeding herds, feeding operations, slaughter and meat processing can operate at most efficient levels under output stability. Given an adequate degree of flexibility to meet short-term variations in livestock marketings, specialized packing plants can be constructed more efficiently and operated at lower costs when farm output cycles are eliminated.

For an individual firm, where profits are a function of price, it is recognized that price variability can lead to increased profits (41). Historically, the large national and regional meat packers have experienced favorable returns on investment during periods of sharply increasing supplies, although substantial losses usually occurred during periods of low livestock supplies. The reduced profits of individual firms can be viewed, however, as a function of the level of meat-packing capacity relative to supplies of livestock rather than of price *per se*. If aggregate processing capacity were brought in line with aggregate livestock supplies and market demands for meat-packing services, then profits of individual packers presumably would improve even under output stability.

From the consumer standpoint, also, a policy of output stabilization can be criticized on grounds that consumer surplus is greater when prices fluctuate about their mean values than when they remain at their mean values (6, p. 242). This argument, of course, is not new; it has been in the literature since its inception by Dupuit (mentioned by Kuhn, 32, p. 74). Moreover, the allegation, even on theoretical grounds, is dependent on a corollary assumption regarding the constant utility of money (24, p. 38). Indeed, the occurrence of an inelastic demand for most agricultural products results in little gain in consumer surplus, given price variability, unless the price decline is quite large (46, p. 192).

For the most part, the hypotheses pertaining to the desirability or lack of desirability of price and output stability in the livestock-meat economy need empirical verification that has been lacking. From the position of the individual consumer, it is recognized that different groups in society react differently to price stability. For example, short-term variability in retail meat prices allows a range of choice in cuts and quality of meat products for the shopper maintaining a given level of food expenditures. Similarly, livestock producers who are superior managers may find that a certain amount of cyclical variability improves their net earnings over time, provided they are able to anticipate the turning points far enough ahead to adjust production plans (20).

The most that can be said about the policy issue of stabilizing price and output cycles in the livestock-meat economy can be summarized as follows: Some degree of price and output variability is not objectionable and, indeed, may be desirable. However, extreme price and output variability in the beef and pork sectors is socially uneconomic and should be avoided on efficiency grounds.

Reducing marketing margins

Reduction of marketing margins is a well-recognized goal of agricultural marketing research. The farmer's share of the consumer dollar accruing to beef and pork producers has been calculated by the United States Department of Agriculture since 1919. Inasmuch as consumer demand reflects the quantity that will be taken at a given retail price, a reduction in marketing margins can be shown to result in higher primary market prices. However, the marketing services may vary with the price level. Thus, a reduction in marketing margins and corresponding services may alter the level of demand and also the pattern of consumer response to price changes.

The goal of reducing marketing margins needs some qualification in light of the need to have margins high enough to provide adequate returns for business innovation and growth. It is possible that too much emphasis is placed on the goal of marketing efficiency and too little on adequate retained earnings for the purpose of introducing innovations in both product and process (62, p. 244). However, reductions in marketing margins are possible, given the present level of marketing services demanded by consumers. Better forecasting, for example, could result in a further minimization of transport cost by reducing cross-hauling. Full participation in a revised grading program that describes product attributes without implying quality differentials could further reduce promotion cost, as well as give more adequate signals to convey consumer

preferences for particular products. In this study, the margins strategy giving the lower retail price for any given consumption level over time will be considered superior in the light of the marketing norm.

Consumer choice

The consumer is faced with the problem, not only of separating the meaning of grade designations, but also of comparing the quality of graded and ungraded meat products. He has little capability as an individual to investigate any possible fraudulent dealings of marketing enterprises. In addition, the pricing policies of the retail outlet he patronizes may result in a totally ineffective transfer of his choices from the meat counter to the livestock producer.

The extent to which consumer choices are taken into account in producer decisions is influenced by the margins polices of the retailing segment. Consider, for example, a fixed compared with a constant percentage markup over wholesale price as alternative margin policies; if the cobweb model is employed, the transmission of consumer choice differs for the two policies. If supplies drop and prices rise accordingly, the variable markup policy allows for a higher derived market price than the fixed markup policy. Depending on the relative elasticities of supply and of demand, the margin strategy used affects the rate of divergence from or convergence to equilibrium over time. The absolute levels of the margins policies, moreover, account for differences in the price response to changes in supply, and ultimately, in the supply response. Therefore, different patterns of market performance will be associated with different margin strategies.

Restricting foreign trade

High domestic prices of low-grade beef, brought about by low levels of cow slaughter, have contributed to a rapid build-up of low-grade beef imports. These imports have tended to reduce the cost of beef in manufacturing. The magnitude of the effect of beef imports on prices of higher grade beef is a subject of current controversy between beef producers and meat importers. The experience of the past few years has indicated, however, that imports of beef do not appreciably affect the net returns of cattle producers, if the imports are maintained at a level no higher than that of the 1958-62 period. During these 5 years, net foreign trade in beef averaged 7 percent of domestic beef production. In this study, therefore, the foreign trade policy goal will be considered as a net import level less than or equal to that of the 1958-62 period.

Because of the scope of the problem, the discussion of beef import levels is confined simply to an evaluation of the price and output effects of a prescribed import quota. Fluctuations and secular trends in beef supplies in the major exporting countries are not included explicitly, except in the trend term of the net import equations.

Maintaining effective competition

The policy goal of effective competition is manifest in several other performance norms (15, p. 112). In the past, the effective competition norm has favored the reasonably free entry of few firms. At the same time, economies of scale, local codes (such as building codes), unionization and initial capital requirements have limited entry of new firms.

As a result of the trend towards monopoly, legal action has been taken to maintain "workable" competition. Since the initial wave of antimerger activity following passage of the Sherman Acts, the courts modified their position to the extent that the size of the firm must actually prevent new firms from entering the industry (21, p. 27). In the past decade mergers also have been approved where evidence indicates that a new firm could achieve cost economies that would allow it to compete with existing firms. Recent cases taken to the Supreme Court, however, show a trend away from merger approvals (36, 18). The impact of these most recent decisions is to limit the growth of large corporations to internal growth.

The results of the Brown Shoe case and subsequent decisions point to a new set of legal restraints on mergers in the future. While entry, exit and the number of firms will not be traced out for alternative market structures by the price-output model to be presented, the changing concepts of effective competition, accompanied by entry and exit consistent with the growth in demand, will be considered when dealing with the alternative market assumptions. Some basic concepts and definitions are reviewed first, however, before further discussion of the alternative market assumptions.[3]

Basic Concepts and Definitions

Among the basic concepts used in this study are norms, strategies, models, structure and simulation. Norms include objective functions, goals and decision rules. An objective function is a choice criterion which may be maximized or minimized. Goals are objectives toward which the economy or society directs its energies or concerns. Decisions are statements of choice for a specified set of conditions or events that a particular decision unit may face.

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[3] A more complete discussion of certain technical points pertaining to the alternative market assumptions is presented in an unpublished doctoral dissertation by Richard J. Crom, "Computer Models of Price and Output Determination in the Livestock-Meat Economy." Iowa State University Library, Ames, Iowa, 1964.

Where the decision-maker has discretion, he forms what we call decision strategies or rules.

The concept of market strategy is used in an aggregate sense in this study; it refers to the composite of decisions of individual decision-making units with reference to a particular activity, such as pricing. The aggregate phenomenon is made up of a variety of individual strategies specified by the decision rules of individual firms. In using the concept of a composite strategy, however, we need appropriate assumptions regarding the distribution of decision units, the policies and practices of these units, and the interaction among them.

A model is a set of relationships among a set of variables, the relationships being specified in the form of equations. If the parameters of the equations are given numerical values, we have a particular structure. Thus, a model is a class of structures. While parameters are the constants of the model, variables may take on different values. The levels of endogenous variables are determined by the model. Lagged endogenous variables are endogenous variables whose values are determined by the model in a prior time period. Exogenous variables are variables whose values are determined outside the model.

Two types of relationships are contained in the model—identities and functional relations. Identities specify an exact relationship between variables with no error or disturbance terms. A functional relation "is not necessarily exact, but in general is more or less blurred by random disturbances" (64, p. 7).

Functional relations are further subdivided into behavioral and technical relations. Technical relations are the relationships between two physical quantities; they are essentially engineering data. Behavioral relations describe the consequences of human behavior in decision-making.

When examining the performance of livestock and meat markets, it is helpful to distinguish between economic structure and market structure. Economic structure, in the context of this study, refers to the relations among such variables as production, consumption and prices in a comprehensive system of interdependent events. Market structure encompasses those attributes of an industry that are related in a causal sense to market behavior or conduct; for example, the number, size and geographical distribution of firms, the degree of specialization or diversification, the economies of size, the barriers to entry, the transportation and storage facilities and the quality of market information.

The economic structure of the livestock-meat economy is specified by a model in which the variables are livestock and meat prices, outputs and inventories. The numerical values assigned to the parameters of this model for the 1955-64 period are quite stable; hence, they can be used to depict a particular structure of the livestock-meat economy.

Trend variables are included in several behavioral and technical relations to account for slowly changing productivity and consumer taste. The trend components are not a mask for unknown phenomena that are highly correlated with time, rather, these components serve as a surrogate for the gradually changing phenomena. In making long-run projections, small adjustments must be made in the coefficients of some of the trend terms to account for expected changes in technology and demand.

Finally, simulation is a process of conducting experiments on a model. The object of simulation is to change the values of initial conditions, exogenous variables or relations, and then to trace out the effects of these changes on the time paths of the endogenous variables. The concept of simulation and its comparison with the conventional mathematical technique is discussed later in this report.

BASIC ECONOMIC RELATIONS

The need for identifying the basic economic relationships associated with alternative forms of market organization in the livestock-meat economy was suggested in the Introduction. Before attempting to estimate these relationships, however, a more specific notion of the relevant variables and the cause-effect sequences in the over-all model is needed.

Initially, the variables selected for the study were classified into those exogenous to the system at all times, current endogenous variables, and lagged (predetermined) endogenous variables. Endogenous variables were further classified as inventory variables, production variables, foreign trade variables or price variables. Inventory variables include livestock on hand Jan. 1 and stocks of beef or pork at the end of a production period. Production variables refer to commercial slaughter and meat production. Foreign trade in beef and pork is considered on a net basis; i.e., imports minus exports. Price variables are specified at the retail, wholesale, live and feeder market levels.

Supply and Demand

The complex interactions of the three categories of variables may be depicted by a stock-flow diagram. To reduce space requirements, the variable names are coded following the computer language format used in subsequent chapters. The list of variables, code names and descriptions appears in table 1. The structure is identified on a semiannual basis.

Considerable work has been reported in the identification and estimation of partial supply and demand relations—perhaps more than in developing a comprehensive structure of the several sectors

Table 1. Description of variables used in the computer model of the livestock-meat economy.

Fortran variable name[a]	Unit of measure	Description
H21	1,000 head	"Other" calves less than 1 yr. old on hand Jan. 1.
H22	" "	"Other" heifers 1-2 yr. old on hand Jan. 1.
H23	" "	"Other" cows and heifers over 2 yr. old on hand Jan. 1.
H24	" "	Steers, bulls and stags 1 yr. old and over on hand Jan. 1.
H26	" "	Cattle on feed Jan. 1 in 26 states.
H32	" "	Sows and gilts over 6 months old on hand Jan. 1.
SF31	" "	Sows farrowing Dec.-May.
SF32	" "	Sows farrowing June-Nov.
CS2$_i$	mil. lb.	Commercial cattle slaughter (liveweight).
FIC2$_i$	" "	Federally inspected cow slaughter (liveweight).
FIBCN	1,000 head	Federally inspected cow slaughter, annual basis.
BP2$_i$	mil. lb.	Commercial beef production (carcass weight).
CS3$_i$	" "	Commercial hog slaughter (liveweight).
PP3$_i$	" "	Commercial pork production (carcass weight).
FTR2$_i$	" "	Imports minus exports of beef (carcass weight).
FTR3$_i$	" "	Imports minus exports of pork (carcass weight).
ES2$_i$	" "	Ending stocks of beef in cold storage (carcass weight).
ES3$_i$	" "	Ending stocks of pork in cold storage (carcass weight).
QPH2$_i$	lb.	Per-capita civilian consumption of beef (carcass weight).
QPH3$_i$	"	Per-capita civilian consumption of pork (carcass weight).
PWB2$_i$	$	Wholesale price per 100 lb. of Choice 600-700 lb. steer beef at Chicago.
PWB3$_i$	"	Wholesale value of 100 lb. of pork at Chicago.
P2$_i$L	"	Price of Choice steers at Chicago.
P3$_i$L	"	Price per 100 lb. of U.S. No. 1, 2 and 3 grade 200-220 lb. barrows and gilts at Chicago.
P2L	"	Annual average of P2$_i$L.
P3L	"	Annual average of P3$_i$L.
P2$_i$FC	"	Average price per 100 lb. of Good and Choice 300-500 lb. steer calves at Kansas City.
P2FC	"	Annual average of P2$_i$FC.
P2LFS	"	July 1 through June 30 average of P2$_i$L.
AWFS$_i$	lb.	Average weight of steers slaughtered under federal inspection.
T$_i$	b	Time.
OMH$_i$	lb.	Output per man-hour in the meat-packing industry.
RM2$_i$	$	Retail margin per 100 lb., Choice grade steer beef, Chicago.
RM3$_i$	"	Retail margin per 100 lb., pork, Chicago.
P6$_i$	"	Average price of No. 3 corn, Chicago.
P6	"	Annual average price of No. 3 corn, Chicago Nov. 1, Oct. 30.
HCP$_i$	mil.	U.S. civilian population at midpoint of semiannual period.
HF6	1,000 bu.	Stocks of corn on farms Jan. 1.
H13	1,000 head	Dairy cows 2 yr. old and over on hand Jan. 1.
AMC2$_i$	mil. lb.	Military consumption of beef (carcass weight).
AMC3$_i$	" "	Military consumption of pork (carcass weight).
YPH$_i$	$	Per-capita disposable personal income.
CPI	----	Consumer price index.
RANGE	----	Oct. 1 range conditions in 17 western states.
AMRGE	----	April-May range conditions in 17 western states.

a i = 1, Jan.-June; i = 2, July-Dec.
b i = 1, Annual, 1949 = 1; 2, July-Dec. 1948 = 1; 3, Jan.-June 1949 = 1; 4, Annual, 1964 = 1.

of the livestock-meat economy (5, 7, 8). Many of the analyses of the beef and pork sectors, especially of the pork, have focused on the cobweb theorem.

Inventories

The longer time associated with the cattle cycle led to the addition of inventory theory to the cobweb phenomenon in explaining the cattle cycle. According to the inventory theory of business cycles, the demand for producer goods rises before an increase in the sale of consumer goods occurs, but falls when sales of consumer goods fail to maintain the rate of increase. During periods of rising sales, stocks of consumer goods are built up. When store managers realize sales are falling, orders are cut drastically, not only to be in line with the reduced demand, but also to reduce inventories to "normal" levels (37).

Since meat is a perishable product, all meat produced is consumed at some price soon after it is produced. Few consumers purchase enough meat to affect price individually; therefore, they behave as price takers. Retail outlets, however, buy large quantities of meat from wholesalers, usually packers. With many retail buyers, the orders are large enough to affect the price. In this model of the beef and pork sectors of the livestock-meat economy, the relevant price-making forces will be considered to operate at the wholesale level, with retail prices consisting of the wholesale price plus a retail markup and with live-animal price consisting of the wholesale price minus the live-wholesale margin.

Supply versus sales response

On an individual state basis, farm production of cattle and calves, and hogs, reported on a liveweight basis, is the sum of all marketings for slaughter, out-shipments of nonslaughter animals and the change in inventories from the beginning to the end of the year, minus the in-shipments of nonslaughter animals (feeder and breeding stock).

On a national basis, the inshipments cancel the outshipments of nonslaughter animals, except for the relatively small foreign-trade balance in live animals. Commercial slaughter, used on a liveweight basis in this study, is reported from the state in which the slaughter occurs regardless of the origin of the animal. Data on marketings for slaughter are not available. At the national level, marketings for slaughter should equal commercial slaughter on logical grounds. However, because of different procedures used in the preparation of the two series of estimates, they are not identical.

Farm production represents the producer supply response; it includes the build-up or depletion of inventories as well as the production for immediate slaughter. Commercial slaughter, plus farm slaughter for a given year, is viewed as the sales response (with producers who slaughter animals for their own consumption behaving in the same manner as consumers who purchase from retail outlets). The sales response may be greater than, equal to, or less than the supply response when producers are liquidating, maintaining or building up inventories of breeding stock and feeder animals.

Cattle and calf production must be combined since reported farm production is not identified by these two components. In the case of cattle and calves, explanatory variables of farm production (FP2) and the change in Jan. 1 inventories of all cattle ($\triangle$ H2) is:

$$SL2_t = 1.72 + 0.9415^{**} FP2_t - 0.7463^{**} \triangle H2_t$$
$$(0.0763) \qquad\qquad (0.0924)$$
$$R^2 = 0.962 \qquad (Eq. 1.1)$$

for 1949-62. Total slaughter and farm production

are expressed in billions of pounds liveweight, while the change in all cattle inventories is expressed in units of 1-million head. The estimated coefficient associated with the farm production variable is not significantly different from one. Thus, the discrepancy between total slaughter and farm production is largely explained by the change in inventories. Specifically, a 1-million-head increase in cattle and calf inventories is associated with a 746-million-pound decrease in total slaughter. Since this change in inventories may involve any combination of changes in cows, heifers, steers or calves, the value of the coefficient can be interpreted as the average weight of cattle during the specified period.

In the functional relationship between total hog slaughter and the explanatory variables of farm production and change in inventories, the inventory change is divided between the number of sows and gilts over 6 months of age and all other hogs on hand Jan. 1. Since there are only two components to the hog inventory, the estimated relationship between total hog slaughter and the three explanatory variables is:

$$SL3_t = 1.41 + 0.9091^{**} FP3_t - 0.1800 \, \triangle H32_t -$$
$$ (0.1581) (0.2774)$$
$$0.1066^{**} \, \triangle H31_t$$
$$(0.0242)$$
$$R^2 = 0.865 \qquad \text{(Eq. 1.2)}$$

for 1949-62. The estimated coefficient associated with the farm production variable is less than one but is not significantly different from one. Inventory changes in pigs on feed ($\triangle H31$) is the major factor accounting for the discrepancy between farm production and slaughter in the case of hogs.

In the model used in this study, the supply response has been separated into a sales response component (represented by commercial slaughter) and an inventory change (represented by Jan. 1 inventories and sows farrowing during the year). The estimation of commercial slaughter enables, finally, the estimation of beef or pork production.

Causal ordering

The perishable nature of meat products establishes the supply offered as the major determinant of price in the short run. Moreover, the lag between price formation and the decision to change production, plus the biologic time lag, contribute to an economic structure in which the causal variables are determined during one or more prior time periods. Although some variables are determined during the same time period (e.g., meat production, wholesale price and live price), the causal links describe a sequential series. In short, the economic structure of the livestock-meat economy is basically a series of lagged relations.

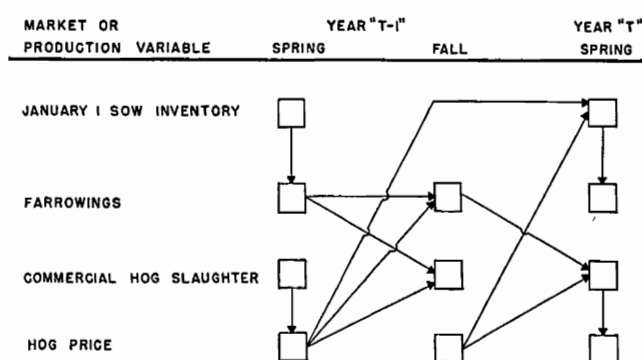The nature of the lagged relationships may be illustrated by examination of a simple model. Con-

Fig. 1. Causal ordering of variables in the hog sector.

sider a closed pork sector as shown in fig. 1. The four variables are live-hog price, the Jan. 1 farm inventory of sows and gilts more than 6 months of age, sows farrowing and commercial hog slaughter.

Commencing in the spring of the year "t-1", we can show that the inventory of breeding stock on hand Jan. 1 accounts for the number of sows farrowing in the spring. Commercial slaughter during this period establishes the level of hog prices. Spring farrowings are important in setting the level of fall farrowings because many producers follow a two-litter system. However, the price received for hogs during the first half of the year is important in establishing the size of the change in fall farrowings. Because approximately 6 months are needed for raising a hog to slaughter weight, spring farrowings are the major determinant of commercial hog slaughter during the last half of the year. Spring hog prices affect fall slaughter through the aggregate of producer decisions to either (a) retain more gilts for breeding purposes and reduce sow slaughter or (b) liquidate breeding stock. Both spring and fall hog prices influence the number of sows and gilts in the Jan. 1 farm inventory, which again is the major source of sows farrowing in the year "t". Commercial hog slaughter in the spring is a function of farrowings, live-hog price and the price of corn the preceding fall, plus a trend term.

In the beef-cattle sector, the longer gestation, growing and feeding periods lengthen the lag intervals. Also, any calf produced may be slaughtered immediately, put on feed or held for breeding. Young breeding stock may be slaughtered or held for breeding.

Let us now consider a closed system of the beef sector with slaughter- or feeder-animal price, Jan. 1 farm inventories of cows, heifers, calves and steers, and commercial cattle slaughter as the only variables. A change in the slaughter-steer and feeder-calf price can be traced through five annual periods as in fig. 2.

Price in year "t-5" is one of the variables determining the number of steers, calves and heifers held in the Jan. 1 farm inventory in year "t-4." Jan. 1 steer and cow numbers determine slaughter in year

"t-4," and the price follows from the level of slaughter. (The elements of the causal sequence shown for years "t-5" and "t-4" will not be traced out in the 4 remaining years for the sake of clarity.) First, note that Jan. 1 cow inventories in the year "t-3" are a result of the addition of heifers from the inventory in the year "t-4" and the subtraction of cows via slaughter in the year "t-4." Jan. 1 calf numbers in year "t-2" are those held from the calf crop produced by cows in the beginning inventory of year "t-3." Similarly, heifer and cow numbers, respectively, follow in years "t-1" and "t."

Pork Sector

The detailed structure of the pork sector is illustrated in fig. 3. The notation used for the variables is identified in table 1. The first numeral in the coding notation (i.e., 2 or 3) refers to beef or pork, respectively, while the second numeral, 1 or 2, refers to the January-June or July-December semiannual period, except in the case of Jan. 1 farm inventories where the second numeral denotes the class of animal. For example, CS31 denotes commercial slaughter of hogs during the first half of the year, whereas SF32 denotes sows farrowing during the second half of the year. However, in the coding notation H32, the first numeral refers to the hog sector as before, but the second numeral, 2, refers to the class of animal, sows and gilts.
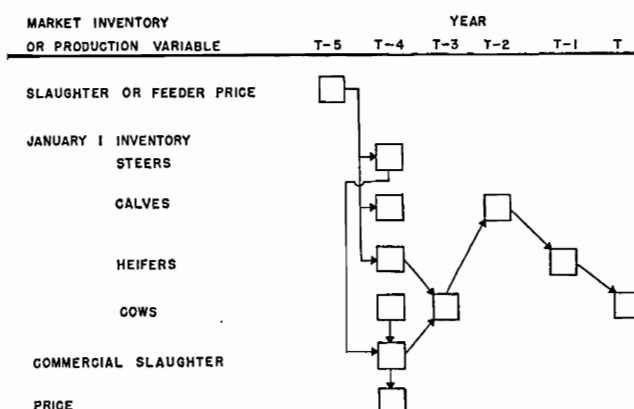
Fig. 2. Causal ordering of variables in the beef sector.

In fig. 3, current endogenous variables appear as circles. Exogenous variables are noted by squares and appear inside the circular recursive flow of endogenous variables. In addition, ending stocks (ES3j) and Jan. 1 sow inventories (H32) are influenced by their own value in the previous period. This association is noted by a circle inside a square. The two interaction points with the beef sector are represented by a diamond-shaped symbol. Time lags on an annual basis are indicated in the lines showing the circuitry of the system as are situations in which the causal variable takes the form of a first difference.

We can approach the circuitry in the pork sector

Fig. 3. Economic structure of the pork sector.

at the point of sows farrowing (SF31) in the first 6 months of the year: Spring farrowings and spring hog price are the endogenous variables affecting commercial hog slaughter the following fall, along with the exogenous variable of corn price, plus a trend effect associated with larger litters. The level of commercial slaughter and a trend in the dressing percentage establish the level of fall pork production. Foreign trade in pork usually is negligible, but must be c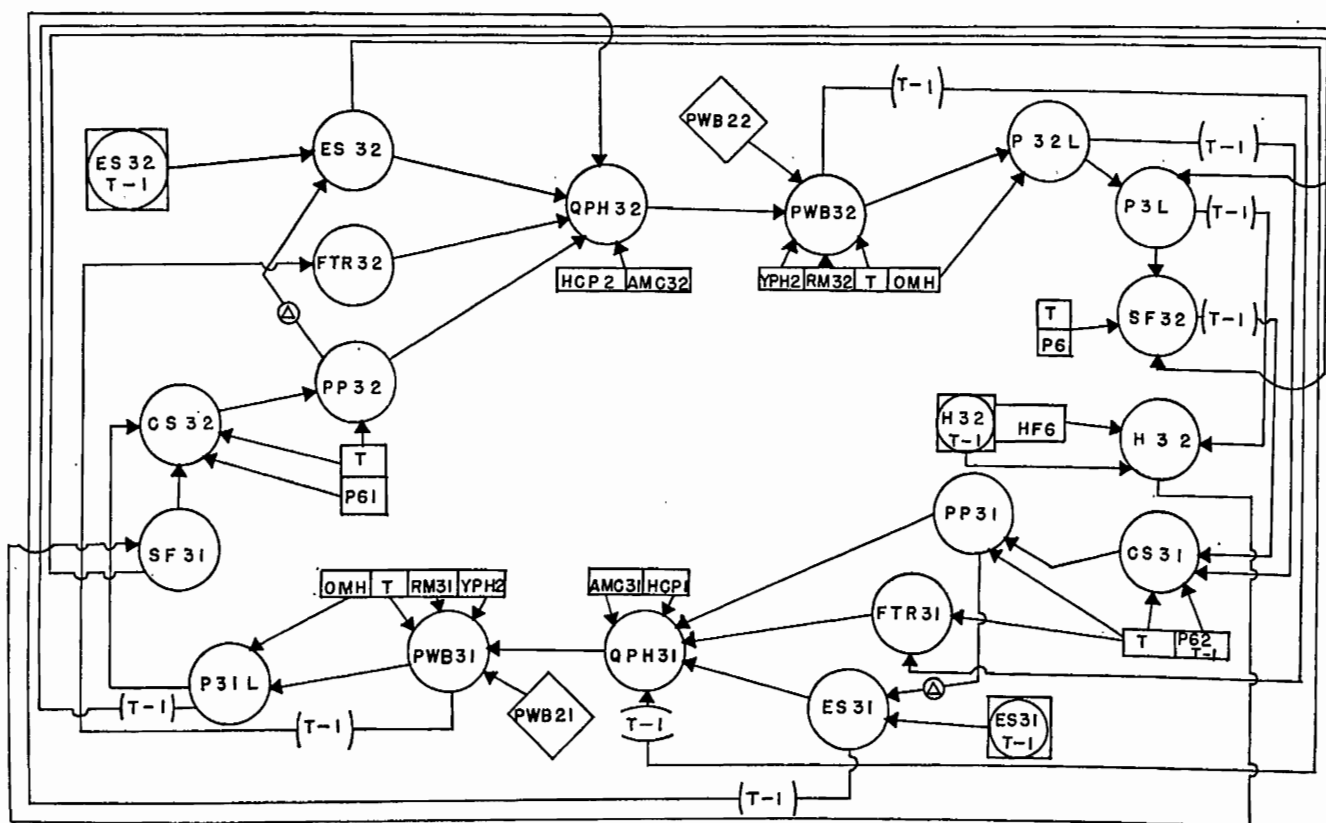onsidered to maintain the consumption identity. Fall imports and exports are influenced by the wholesale price of pork in the preceding spring and a trend toward more foreign trade. Ending stocks shift from their year-earlier level in response to the change in pork production from the preceding fall. Thus, pork consumption takes the form of an identity: Ending stocks on June 30 (ES31), plus fall pork production (PP32), plus net foreign trade (FTR32), minus military consumption (AMC32), minus Dec. 31 stocks (ES32). Military consumption is taken as exogenous. Consumption, finally, is converted to a per-capita basis.

The pork and beef sectors interact at the wholesale price level; they represent the only simultaneous determination in the entire system. Wholesale pork price is a function of per-capita pork consumption, the price of beef, the pork retailing margin, per-capita disposable income, and a trend component denoting shifts in consumer preference. Note that the retailing margin is treated as an exogenous variable in the model. However, the quantity of pork available for consumption and the resulting price do not necessarily have an effect on the margin, although the margin variable is affected by exogenous elements such as wages and demand for more retailing services. The decision to treat the margin as exogenous will be discussed later.

Live-hog price is based on the wholesale price; however, technological efficiency in the packing industry (of which output per man-hour is assumed to be indicative) also affects the live-wholesale margin. Annual live-hog price is an unweighted average of the spring and fall price.

The level of fall farrowings is not determined until the end of the year since the variable is used to explain commercial slaughter the following spring. Although spring farrowings are the major determinant of fall farrowings, the trend denotes a shift towards year-round production. The corn-hog ratio during the year also modifies fall farrowings, since an upturn or downturn in this proxy for expected profits may affect fall farrowings in the latter part of the fall period.

Similarly, the Jan. 1 inventory of breeding stock is affected by the corn-hog ratio of the previous year. In addition, the change in stocks of corn on farms affects the inventory. Because of government price-support programs, all corn prices and stocks are considered exogenous.

The remainder of the causal ordering should be followed easily. Briefly, the sequence is spring slaughter, pork production, consumption, wholesale price and live price.

Beef Sector

Two different forms of the structure of the beef sector are presented in figs. 4 and 5. The latter form is included because of its superior performance, which will be discussed later.

Only two different forms of notation need to be introduced. Some endogenous variables are affected by the rate of change in a causal variable. The causal variable in this case is the second difference of that variable, $(X_t-X_{t-1}) - (X_{t-1}-X_{t-2})$. This form is noted as $\triangle^2$. The notation, E, refers to a second difference calculated on a semiannual basis.

The original form of the structure of the beef sector is presented in fig. 4. Commercial cattle slaughter in the first half of the year (CS21) is determined by the absolute level of Jan. 1 steer numbers, the rate of change in beef-cow numbers and the rate of change in the current spring feeder price. The rate of change in cow numbers is indicative of the build-up or liquidation of breeding stock, whereas the rate of change in the feeder price is indicative of a diversion of feeder stock to slaughter during low-price periods. Although the current value of the causal variable (P21FC) comes into play, the recursiveness of the system is maintained in that the spring price is determined by lagged variables.

In light of the detailed explanation of the pork sector, the causal chain can be followed easily through the determination of the fall feeder price. The only difference in this portion of price and output determination is the use of federally inspected cow slaughter (FIC2j) lagged 6 months as a causal variable.

In the feeder-price sector, the annual average feeder price (P2FC) is a factor affecting the Jan. 1 inventory of cattle on feed (H26); a change in the latter from the year before, along with the feeder price the preceding fall, determines the spring feeder price. The fall feeder price affects the level of spring price since more feeder calves are sold in the last half of the year. An increase or decrease in cattle on feed Jan. 1 is associated with a change in demand for feeder cattle.

The annual feeder price of the preceding year is indicative of the profitability of the beef sector and is an important determinant of several Jan. 1 inventory variables—cattle on feed, steers and calves. The number of cows and heifers of breeding age responds more quickly to price change; the slaughter price (P2L) is the appropriate causal variable. Numbers of steers, heifers and cattle on feed are partly determined by the number of calves less
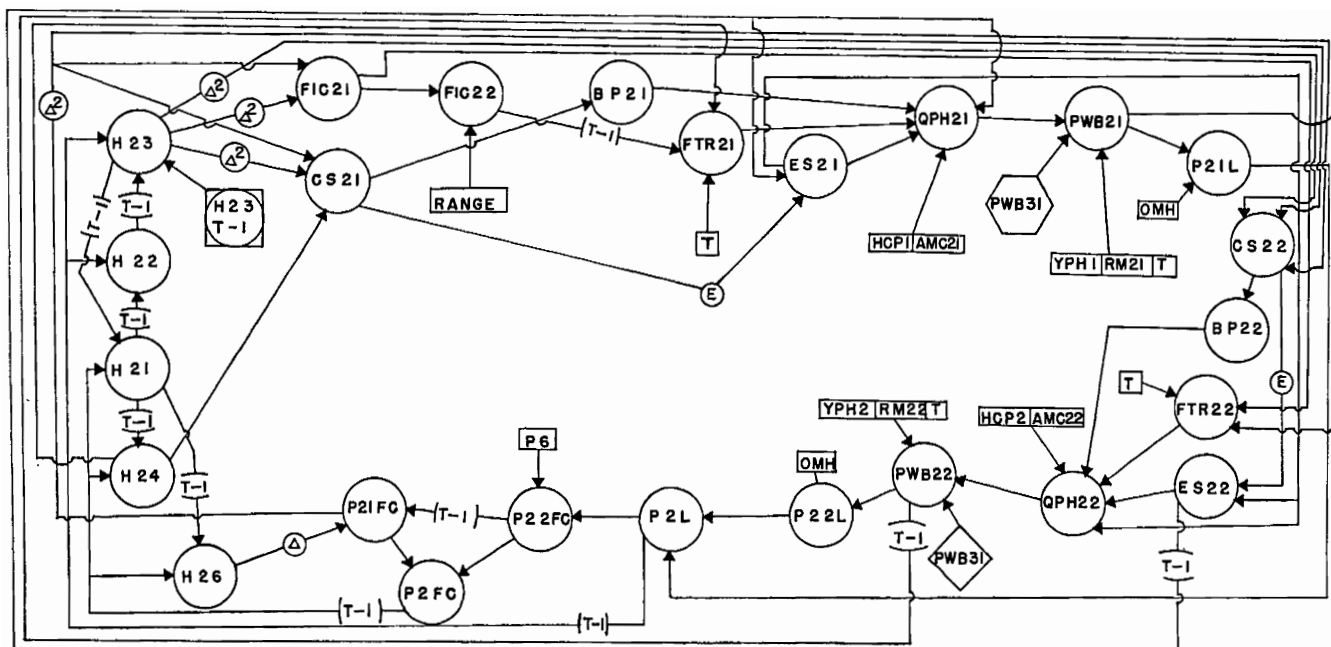
Fig. 4. Economic structure of the beef sector.
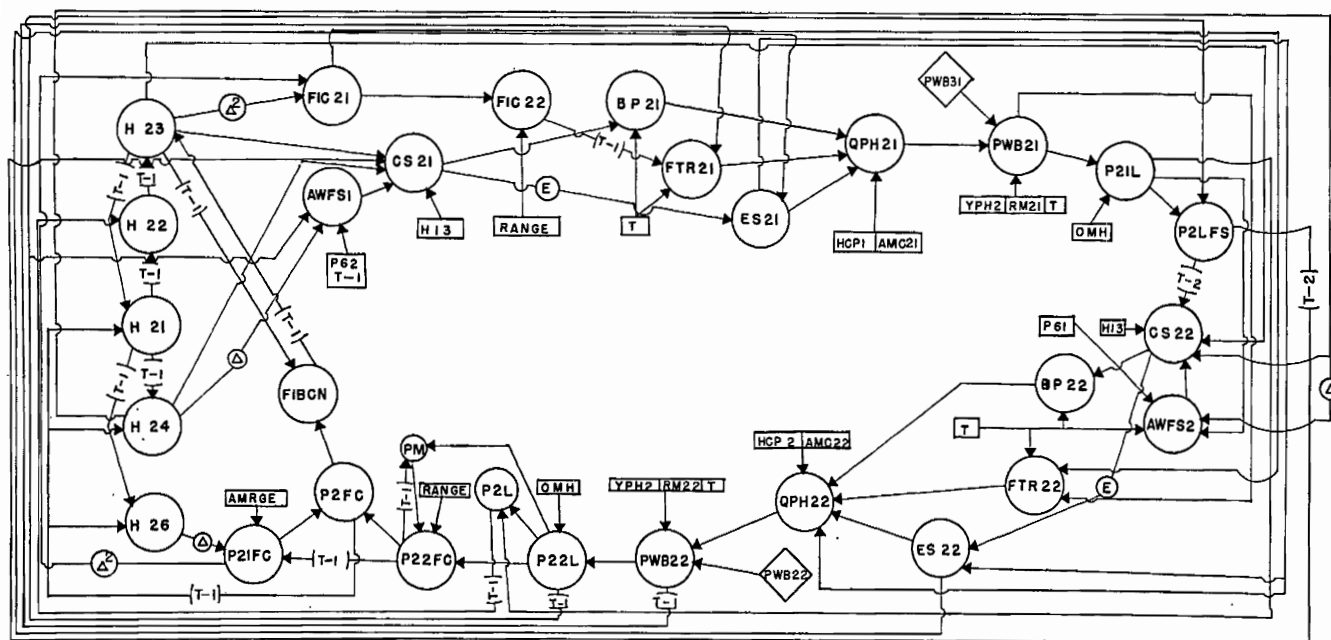
Fig. 5. Alternative economic structure of the beef sector.

than 1 year of age the previous year. In addition to the price effect, Jan. 1 cow numbers respond to a change in heifer numbers the previous year.

The principal differences in the alternative structure presented in fig. 5 occur in the determination of commercial slaughter, feeder-calf price and Jan. 1 cow inventories. The basic causal variables of commercial cattle slaughter are the absolute levels of the Jan. 1 inventory of steers, beef cows and dairy cows. However, since slaughter is estimated on a liveweight basis, average slaughter weight, especially that of steers, is important. Also, a supply

price—the average slaughter price on a July-to-June basis lagged 2 years—exerts a significant effect on the level of commercial slaughter. Although at first the 2-year lag appears excessive, it has a plausible empirical basis. Decisions to breed more cows are usually made about July 1. If price the preceding year is favorable, more cows are bred during the summer of year "t-2." This results in a larger calf crop in year "t-1," of which part is slaughtered in year "t." Before leaving the revised structure of commercial slaughter, it can be noted that the estimation of Jan. 1 dairy-cow inventories

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involves all exogenous variables. The dairy-cow variable is considered exogenous to the beef sector.

Average steer weights may change as a result of cattle numbers, the beef-corn ratio of the preceding half-year and a trend component. The trend, in this instance, stems from the increasing ratio of fed steers to total steers slaughtered.

The fall feeder price may still be considered a function of the slaughter-steer price; however, this price also is influenced by the feeding margin, PM, and range conditions. The feeding margin, illustrated in the structural diagram, is computed as a current margin; however, the margin in the spring appears more appropriate when steer prices are stable or gradually rising (possibly because cattle feeders do not calculate margins as closely when prices are favorable). Good range conditions logically support feeder prices since the rancher's bargaining power is sustained by abundant feed supplies for wintering. Spring feeder price is calculated as in the original model, with the addition of an effect associated with spring range conditions.

The beef-cow inventory on Jan. 1 may be regarded as a basic stock variable with additions coming from heifers the previous year and deletions for cow slaughter the previous year. The cow-slaughter variable includes only federally inspected slaughter to maintain consistency in variables throughout the study. However, at this stage, cow slaughter should be regarded as total cow slaughter (determined by the current feeder price). Inasmuch as cow slaughter is determined as an ex-post relation at the end of this year, the lagged nature of the system is maintained.

ECONOMETRIC MODELS AND PROCEDURES

To study the performance of the livestock and meat markets and to compare alternative forms of organization of these markets, the parameters for a model containing the relevant prices, outputs and inventories must be estimated. The estimated parameters for the model must be prepared so as to generate the time paths of variables over the length of one or more production cycles, when cycles exist. The estimates must be obtained through the analysis of time-series or cross-sectional data. Accordingly, the specification of the basic economic model must be followed by the estimation of the specific functional relationships.

For this study, it was decided to use the single-equation, least-squares approach to estimate the functional relations of the models. Possible difficulties of the assumption of uncorrelated error terms of the recursive model, plus some autocorrelation in the time-series data, were taken into account in making this decision. However, anticipated use of other types of decision rules and behavioral relations in the simulation model were additional considerations. These latter factors, combined with

the advantage of computational simplicity, outweighed the disadvantages, particularly in light of the limited number of observations available in the post-World-War-II period. Finally, all equations involving a high degree (i.e., the simple correlation, r, exceeds 0.80) of multicollinearity were reestimated after eliminating the variable in question.

All the preliminary series of estimates of the basic economic relations were based on data from either the 1949-60 or the 1949-61 period. In several cases, however, revised estimates using 1955-63 data were needed when initial simulation runs revealed changes in some relations since the Korean conflict.

With the exception of feeder-calf price, Chicago prices were used to minimize the spatial price variation problem. Quantity variables were estimated on a liveweight or carcass-weight basis, with the exception of livestock inventory variables, estimated on a 1,000-head basis. Although the variable notation will be described in the discussion of each functional relation, refer again to table 1 for a detailed description of the variables.

In the discussion that follows, standard errors of the estimated coefficients are presented in parentheses below the coefficient. One asterisk to the right of the coefficient denotes a "t" test indicating the estimated coefficient is significantly different from zero at the 5-percent level; two asterisks indicate significance at the 1-percent level.

Livestock Inventory Sector

All Jan. 1 beef-cattle inventory equations are based on data covering the entire 1955-64 period. Beef-cow numbers on Jan. 1 (H23) are estimated as a function of the lagged value of the dependent variable, the first difference of the beef-heifer inventory lagged 1 year, and the average price of steers the preceding year. The accelerator coefficient associated with the lagged value of the dependent variable is indicative of the growth of the beef industry during the postwar years. Similarly, the magnitude of the coefficient associated with the change in heifer inventories the previous year indicates the average number of yearling heifers retained for the cow herd. The beef-cattle inventory equations are summarized as follows:

$$H23_t = -4,773.0 + 1.045^{**} H23_{t-1} + 0.7891 \, \triangle H22_{t-1}$$
$$(0.056) \qquad (0.4572)$$
$$+ 168.2^* P2L_{t-1},$$
$$(64.3)$$
$$R^2 = 0.976 \qquad (Eq. 2.1)$$

$$H21_t = -11,990.0 + 1.077^{**} H23_{t-1} + 166.2^{**}$$
$$(0.086) \qquad (25.1)$$
$$P2FC_{t-1},$$
$$R^2 = 0.974 \qquad (Eq. 2.2)$$

$$H22_t = -3,418.0 + 0.3361^{**} H21_{t-1} + 142.4^* P2L_{t-1},$$
$$(0.0692) \qquad (45.5)$$
$$R^2 = 0.900 \qquad (Eq. 2.3)$$

$$H24_t = -4{,}017.0 + 0.7061^{**} \, H21_{t-1} + 81.26^{**}$$
$$(0.0435) \qquad (13.13)$$
$$P2FC_{t-1},$$
$$R^2 = 0.987 \qquad \text{(Eq. 2.4)}$$

$$H26_t = -6{,}132.0 + 0.5735^{**} \, H21_{t-1} + 70.96^{*} \, P2FC_{t-1}.$$
$$(0.0555) \qquad (20.94)$$
$$R^2 = 0.958 \qquad \text{(Eq. 2.5)}$$

Thus, the inventory of beef calves less than 1 year of age (H21) is depicted as a function of the number of beef cows (H23) the preceding Jan. 1 and the average price of feeder calves during the preceding year. The coefficient greater than 1 associated with beef-cow numbers is plausible inasmuch as male dairy calves are included in this inventory classification. The number of beef heifers 1 to 2 years old (H22) is determined by the number of beef calves the preceding Jan. 1 and the price of slaughter cattle. Slaughter price gives a slightly better explanation of the variation in beef-heifer inventories than feeder price, whereas, in equation 2.4 in which the number of steers and bulls over 1 year of age on hand Jan. 1 (H24) is estimated, the feeder price for the preceding year is again the more appropriate price variable. Finally, the number of cattle on feed Jan. 1 in the 26 major feeding states is related to the same set of explanatory variables as steer and bull inventories. This is not surprising since cattle on feed constitute a multiple classification; they are also classified in the inventory as steers, heifers or calves.

Only one Jan. 1 inventory variable is necessary in the pork sector—the number of sows and gilts 6-months old or over (H32). The hog inventory relationship is estimated as a difference equation:

$$\triangle \, H32_t = -3{,}360.0 + 252.9^{**} \, (P3L/P6)_{t-1} - 2.680^{**}$$
$$(50.80) \qquad (0.800)$$
$$HF6_t.$$
$$R^2 = 0.880 \qquad \text{(Eq. 2.6)}$$

The change in sow and gilt numbers is related to the corn-hog ratio and the change in Jan. 1 stocks of corn on farms. While a change in the corn-hog ratio is a logical causal variable, caution must be exercised in interpreting the change in stocks of corn on farms. First, government stocks held on farms are included in the figure. Hence, a change in participation in price-support programs could have an important effect on the magnitude of this variable. Secondly, a decrease in animal units consuming corn or a change in a specific class of animal consuming corn during the last half of the preceding year may result in an increase in Jan. 1 corn stocks. Finally, the size of the fall corn crop may affect the level of corn stocks. All these possibilities of increasing (decreasing) corn stocks and the related decreases (increases) in sow and gilt numbers must be considered. A logical explanation of the change in Jan. 1 corn stocks is offered by the alternatives of (a) a decline in livestock feeding or participation in government programs resulting in more corn on farms the following Jan. 1 and (b) a less favorable outlook for hog production with a corresponding reduction in sow and gilt numbers.

Finally, the number of sows farrowing during the December-May period and the June-November period are included with the inventory variables, although these variables are not stock variables. However, the sows-farrowing variables function in the same manner as cattle inventories with reference to commercial slaughter. The functional relationships for sows farrowing in the spring and fall, respectively, are:

$$SF31_t = -165.0 + 0.9206^{**} \, H32_t,$$
$$(0.0530)$$
$$R^2 = 0.974 \qquad \text{(Eq. 2.7)}$$
and

$$SF32_t = -3{,}200.0 + 0.7249^{**} \, SF31_t + 210.4^{**}$$
$$(0.2173) \qquad (39.0)$$
$$T + 82.0 \, (P3L/P6)_t.$$
$$(51.9)$$
$$R^2 = 0.880 \qquad \text{(Eq. 2.8)}$$

The simple regression of sows farrowing in the spring (SF31) on the Jan. 1 inventory is obvious. Fall farrowings (SF32) are based on spring farrowings with an additional influence coming from the corn-hog ratio as the year progresses. A trend toward year-round farrowing also is verified by the analysis. Equation 2.7 is based on 1953-61 data, while equation 2.8 is based on 1955-62 data.

Livestock Slaughter and Meat Production

Commercial cattle slaughter, estimated over the 1949-60 period, is a function of the rate of change in beef-cow numbers, the number of steers on hand Jan. 1 and the rate of change in feeder-calf prices during the first half of the year. The rate of change in a variable such as beef-cow numbers or feeder-calf prices is measured by the second difference of the variable. Since the spring feeder price is determined by lagged variables, the recursive nature of the system is thereby maintained in the following equations for estimation of semiannual commercial slaughter:

$$CS21_t = -3{,}926.0 - 0.7601^{*} \, \triangle^2 \, H23_t + 1.398^{**}$$
$$(0.2526) \qquad (0.181)$$
$$H24_t + 83.12^{*} \, \triangle^2 \, P21FC_t,$$
$$(25.24)$$
$$R^2 = 0.923 \qquad \text{(Eq. 2.9)}$$
and

$$CS22_t = -3{,}356.0 - 0.9236^{**} \, \triangle^2 \, H23_{tt} + 1.434^{**}$$
$$(0.2370) \qquad (0.169)$$
$$H24_t + 68.24^{*} \, \triangle^2 \, P21FC_t.$$
$$(23.66)$$
$$R^2 = 0.938 \qquad \text{(Eq. 2.10)}$$

The negative coefficient associated with the rate of change in beef-cow numbers is logical in that

slaughter of breeding stock is reduced as cattle numbers are being built up. Conversely, the sales response is presented by increased slaughter as the feeder price increases at an increasing rate. Also, more feeder calves are diverted to slaughter during periods of low prices. The Jan. 1 number of steers on hand is important in setting the level of slaughter for the year. Finally, the sum of the coefficients of the steer inventory, approximately 2.84, is affected by a feeding period averaging less than 1 year.

Cow slaughter under federal inspection (FIC2j) can be estimated as a function of the rate of change of Jan. 1 cow numbers and spring feeder prices during the first half of the year. However, federally inspected cow slaughter during the fall is determined by cow slaughter during the first half of the year and the fall range conditions, as indicated by the Oct. 1 range condition report for the 17 western states. Cow slaughter, therefore, is the only federally inspected component necessary for the model. Thus, the two equations denoting the first and second half-year semiannual estimates of cow slaughter under federal inspection on a liveweight basis are:

$$FIC21_t = 2{,}257.0 - 0.3084^* \triangle^2 H23_t + 21.84^*$$
$$(0.1469) \qquad (10.58)$$
$$\triangle^2 P21FC_t,$$
$$R^2 = 0.801 \qquad (Eq.\ 2.11)$$

and

$$FIC22_t = 4{,}874.0 + 0.9050^{**} FIC21_t - 53.10^*$$
$$(0.2690) \qquad (18.64)$$
$$RANGE_t.$$
$$R^2 = 0.790 \qquad (Eq.\ 2.12)$$

The rate of change in feeder price represents the profitability of feeder-calf sales, while the coefficient associated with the rate of change in cow numbers again represents the build-up or decrease in the breeding herd.

Estimation of commercial hog slaughter (CS3j) on a liveweight basis requires a separate equation for each period, since different lags are needed in the variables. The semiannual equations are:

$$CS31_t = 284.0 + 1.334^{**} SF32_{t-1} - 57.57^* P32L_{t-1} +$$
$$(0.133) \qquad (25.09)$$
$$1{,}198^* P62_{t-1} + 72.90^* T1,$$
$$(388.0) \qquad (24.43)$$
$$R^2 = 0.962 \qquad (Eq.\ 2.13)$$

and

$$CS32_t = 99.0 + 0.7764^{**} SF31_t - 16.10\ P31L_t +$$
$$(0.1152) \qquad (19.81)$$
$$861.4^* P61_t + 238.6^{**} T1.$$
$$(367.9) \qquad (27.50)$$
$$R^2 = 0.941 \qquad (Eq.\ 2.14)$$

Thus, sows farrowing the previous half-year are associated empirically with the level of commercial hog slaughter. The coefficient for sows farrowing

in the spring is less than that on fall farrowings since more gilts are retained for breeding purposes from spring farrowings. Conversely, more sows are slaughtered in the second half of the year. The effect of fall hog price (P32L) on spring slaughter is significant, but spring hog price has little effect on fall slaughter. Fall hog prices appear to affect the number of gilts retained for breeding purposes. High corn prices (P6j) in the preceding half-year induce more slaughter during the current period insofar as fewer sows are bred for another litter because of the high feed price and are subsequently slaughtered during the next 6 months after the previous litter is weaned. The positive trend terms represent the increase in slaughter over time as litter size increases.

Beef and pork production is closely associated with commercial slaughter. The highly significant trend terms result from (a) an improved dressing yield that is associated with superior technology at the packing plant and (b) a higher percentage of fed cattle and more meat-type hogs. These equations, estimated as one function for both semiannual periods, are summarized by the forms:

$$BP2j_t = 103.0 + 0.501^{**} CS2j_t + 31.50^{**} Tj,$$
$$(0.0258) \qquad (4.10)$$
$$R^2 = 0.980 \qquad (Eq.\ 2.15)$$

and

$$PP3j_t = 256.0 + 0.5258^{**} CS3j_t + 9.576^{**} Tj.$$
$$(0.0146) \qquad (1.325)$$
$$R^2 = 0.989 \qquad (Eq.\ 2.16)$$

Ending Stocks of Meat

December 31 and June 30 stocks of beef and pork form part of the consumption identity. Equations for estimating these variables were fitted initially to the data of 1949-60. Since a substantial reduction in pork inventories took place about 1955, the equations were re-estimated using data for 1955-62.

Since a separate equation is needed for each semiannual period, the two equations are:

$$ES31_t = 134.0 + 0.4770^* ES31_{t-1} + 0.1152^{**} \triangle$$
$$(0.2601) \qquad (0.0364)$$
$$PP31_{t-1},$$
$$R^2 = 0.681 \qquad (Eq.\ 2.17)$$

and

$$ES32_t = 68.0 + 0.6245^{**} ES32_{t-1} + 0.1020^{**}$$
$$(0.1610) \qquad (0.2433)$$
$$\triangle PP32_{t-1}.$$
$$R^2 = 0.799 \qquad (Eq.\ 2.18)$$

The time subscript notation must be observed carefully: ES31 refers to June 30 stocks while ES32 refers to Dec. 31 stocks. The t-1 subscript on the pork production variable refers to the annual first difference in the 6-month period immediately preceding the ending-stock date.

Whereas the percentage of explained variation in the pork-stocks equations is still not as high as in other equations, the performance of the equations is acceptable. However, this lagged model gives unsatisfactory results in estimating beef stocks. After trying several alternative models, the one found most satisfactory is the difference-equation model,

$$ES2j_t = 0.04829^{**} \triangle^2 CS2j_{t-1}.$$
$$(0.00492)$$
$$R^2 = 0.799 \qquad (Eq. 2.19)$$

The same notation applies as in the case of the pork-stocks equations. However, the first and second differences used are semiannual differences; e.g., the Dec. 31 to June 30 change in beef stocks (ES21) is a function of the change in the difference in commercial cattle slaughter between the first and second halves of the year t-1 and the second half of the year t-1 and the first half of the year t.

Foreign Trade in Meat

Instead of estimating imports and exports separately, the foreign trade equations are estimated on a net trade balance basis; i.e., imports minus exports. Several models, in which both domestic and various foreign meat prices were used, have shown that the foreign price coefficients are statistically not significant. Hence, the final estimates of the net foreign trade equations contain no foreign price variables; they are:

$$FTR2j_t = 142.0 + 8.660^* PWB2j_{t-1} - 0.09880^{**}$$
$$(3.518) \qquad (0.02976)$$
$$FIC2j_{t-1} + 16.45^{**} Tj,$$
$$(2.52)$$
$$R^2 = 0.744 \qquad (Eq. 2.20)$$

and

$$FTR3j_t = -156.0 + 2.321^* PWB3j_{t-1} + 3.930^{**} Tj.$$
$$(0.846) \qquad (0.580)$$
$$R^2 = 0.678 \qquad (Eq. 2.21)$$

Both beef and pork equations include the wholesale price at Chicago, PWB2j (or PWB3j), and trend as explanatory variables. The trade balance equation for beef (FTR2j) also includes federally inspected cow slaughter on a liveweight basis as a causal variable. In both equations, an increase in domestic wholesale price during the preceding 6-month period generates increased imports the following 6-month period. Beef imports vary inversely with the level of domestic cow slaughter.

Consumer Demand Equations

A demand equation was estimated for both beef and pork on a semiannual basis. These equations were originally estimated with per-capita consumption as the dependent variable under the assumption that the consumer is a price taker and a quantity adjuster. Explanatory variables used in each equation were the wholesale price of beef, wholesale price of pork, per-capita disposable income, own retail margin, time and a dummy variable for a possible semiannual intercept shift. Inspection of the residual term also suggested use of another dummy variable in the beef-consumption equation during the Korean conflict period. The income and retail margin variables were used in the form of deviations from trend to cope with the multicolinearity problem in the trend variable. The wholesale-retail margin used is *not* the margin reported in the *Marketing and Transportation Situation*. This margin is based on the Chicago price to maintain spatial consistency.

The consumer demand equations, in their original quantity-dependent form, are:

$$QPH2j_t = 48.8 - 0.5227^{**} PWB2j_t - 0.5821^{**} (RM2j-$$
$$(0.0424) \qquad (0.1130)$$
$$\overline{RM2j})_t + 0.5386^{**} Tj + 0.004080 (Y/H-\overline{Y/H})_t +$$
$$(0.0231) \qquad (0.005525)$$
$$0.08435^* PWB3j_t - 1.096^{**} W1 + 1.963^* WK,$$
$$(0.03047) \qquad (0.264) \qquad (0.790)$$
$$R^2 = 0.990 \qquad (Eq. 2.22)$$

and

$$QPH3j_t = 39.0 - 0.3203^{**} PWB3j_t - 0.1761 (RM3j-$$
$$(0.0264) \qquad (0.1603)$$
$$\overline{RM3j})_t + 0.0196^{**} (Y/H-\overline{Y/H})_t + 0.1300^{**} PWB-$$
$$(0.00450) \qquad (0.0251)$$
$$2j_t - 0.02871 Tj - 1.120^{**} W1.$$
$$(0.01678) \qquad (0.242)$$
$$R^2 = 0.923 \qquad (Eq. 2.23)$$

The price relationship in both equations is highly significant. The retail margin and the time variables in the pork equation are significant at the 10-percent level. The standard error of the coefficient of the income variable in the beef-consumption equation is larger than the coefficient; therefore, the derived effect of the income variable is incorporated in the constant term at its mean value.

When the equations are transformed to own-price dependent, the coefficient for per-capita beef consumption (QPH2j) is –1.91, and the coefficient for per-capita pork consumption (QPH3j) is –3.12, which suggests the importance of accuracy in estimating commercial slaughter — the major variable in the consumption identity. An error of 1 pound in the estimation of per-capita consumption, for example, results in a $2-$3 error in wholesale price.

Brandow (7, p. 17) recently estimated demand relations for several agricultural products. For 1955-57, he estimated the elasticity of demand for beef with respect to its own retail price as –0.95 and the cross-elasticity of demand for beef with respect to the retail price of pork as +0.10. Using 1955-57 averages of per-capita consumption and wholesale price and the appropriate coefficients in equation 2.22, the elasticity of demand for beef with respect to its own wholesale price is –0.50, and the cross-

elasticity of demand for beef with respect to the wholesale price of pork is +0.09.

The elasticity of demand for pork with respect to its own retail price was calculated by Brandow as −0.75 for 1955-57. His estimate of the cross-elasticity of pork with respect to the retail price of beef was +0.13. The elasticity of demand for pork with respect to its own wholesale price calculated for the same 3 years by using equation 2.23 is −0.45, while the cross-elasticity of demand with respect to wholesale beef price is +0.17.

Margin Equations

Cattle and hog prices were estimated as a function of the wholesale price and output per man-hour (OMH) in the meat-packing industry. Choice steer prices were used as the live-price indicator to maintain quality consistency. The price of U.S. No. 1, 2 and 3 hogs weighing 200 to 220 pounds was considered representative of the hog market.

The live-to-wholesale margin equations are functions developed from 1949-60 data on a semiannual basis; these two margin equations are:

$$P2jL_t = -1.50 + 0.6397^{**} PWB2j_t - 0.01450^{**} OMH_t,$$
$$(0.0162) \qquad (0.00462)$$
$$R^2 = 0.990 \qquad (Eq. 2.24)$$

and

$$P3jL_t = -2.97 + 0.5749^{**} PWB3j_t - 0.02840^{**} OMH_t.$$
$$(0.0312) \qquad (0.00710)$$
$$R^2 = 0.953 \qquad (Eq. 2.25)$$

Inspection of the reported data shows that output per man-hour in the meat-packing industry increased by about 5 pounds per year from 1949 through 1961. Because of this high correlation with time ($r = 0.97$), the variable is serving as proxy for a trend component. (An alternative model using output per man-hour in a deviation-from-trend form yielded a coefficient that was not statistically significant. The negative coefficient is interpreted, therefore, as a widening of the live-to-wholesale margin over time.)

Fall feeder-calf price is related to the average annual steer price, the price of corn during the year and its own year-to-year change. Inclusion of the first difference of the dependent variable is necessary to adjust the previous coefficients for the trend in feeder price.

The original form of the fall feeder equation is:

$$P22FC_t = 0.26 + 1.557^{**} P2L - 11.46^* P6_t +$$
$$(0.175) \qquad (3.50)$$
$$0.2687^* \triangle P22FC_t.$$
$$(0.0912)$$
$$R^2 = 0.940 \qquad (Eq. 2.26)$$

The $1.56 change in feeder price for every $1 change in steer price reveals the sensitivity of the feeder market to the changing conditions in final demand and supply.

An algebraic solution for equation 2.26 gives the final form of the fall feeder price equation as:

$$P22FC_t = 0.35 + 2.130 P2L_t - 15.68 P6_t$$
$$- 0.3675 P22FC_{t-1}.$$
$$(Eq. 2.27)$$

Since the bulk of light feeder calves moves to market in the fall, the price level for the marketing year is largely determined in the fall. Some seasonal price rise usually occurs in the spring. However, the spring feeder market is also affected by the change in the number of cattle on feed Jan. 1. If the number of cattle on feed Jan. 1 increases, marketings of fed cattle during the first half of the year will be higher than the year before. These heavier marketings tend to depress steer and feeder prices. The functional form of the spring feeder price equation is:

$$P21FC_t = 0.75 + 1.073^{**} P22FC_{t-1} - 0.006721^*$$
$$(0.165) \qquad (0.002964)$$
$$\triangle H26_t.$$
$$R^2 = 0.848 \qquad (Eq. 2.28)$$

ALTERNATIVE BEHAVIORAL RELATIONS

Initial series of simulations over the historical period 1955-64 revealed unsatisfactory results with reference to three functional relations. In the estimating relationships for beef-cow inventories, the coefficient associated with the lagged dependent variable failed to yield satisfactory estimates. The cyclical downturn of the 1956-58 period was not predicted, while cow numbers increased too rapidly.

A second difficulty centered around the commercial cattle slaughter equation. The second-difference model performed well as long as the estimated time paths of the components of the second differences followed the actual time path. However, only a moderate deviation from reported data produced a large divergence in the second-difference variables, resulting in a large error in predicted cattle slaughter.

Finally, the fall feeder-price equation yielded some unrealistic estimates of feeder price. Part of this difficulty may have been due to the formulation of the relationship based on its own first difference, but another factor is the need for a different type of relationship to predict relatively stable feeder prices in the early 1960's.

In the reformulation of the three equations, two additional behavioral relations are required to estimate inputs. These revisions represent the alternative economic structure of the beef sector.

Revised Behavioral Relations

Beef-cow inventories

Inspection of the classification of Jan. 1 livestock inventories reveals that an animal may be classified

in one of the categories at only one period of its life span, except in the case of cows 2 years old and over, where the same classification may apply for several years. Hence, the beef-cow inventory classification is viewed as a reservoir of breeding stock to which additions are made from the heifer inventory the previous year and from which deletions are made in the form of cow slaughter and deaths. We already have an estimating equation for heifer inventories.

Instead of commercial cow slaughter, cow slaughter occurring under federal inspection, which includes both beef and dairy cows, is reported. Examination of data concerning dairy cows (53) and discussions with professional workers in dairy marketing yielded evidence that the component of federally inspected cow slaughter attributable to dairy cows is a fairly constant percentage of the previous Jan. 1 dairy-cow inventory—approximately 22 percent. Therefore, federally inspected beef-cow slaughter (FIBCN) was estimated by subtraction of 22 percent of the Jan. 1 dairy-cow inventory (H13) from federally inspected cow slaughter.

A behavioral relation was developed for estimation of beef-cow inventories by using the synthesized variable of federally inspected beef-cow slaughter. The residual,

$$R23_t = H23_t - (H22_{t-1} + H23_{t-1}),\qquad\text{(Eq. 3.1)}$$

was calculated.

The residual expression assumes that all beef heifers on hand Jan. 1 the previous year are held for the cow herd the following year. The residual was then plotted against the synthesized federally inspected cow-slaughter variable for 1955-64. A scatter-diagram analysis suggested an intercept shift starting Jan. 1, 1960. This shift was explained by a corresponding shift to feeding a larger number of heifers commencing in 1958. (The heifers were classified as beef heifers 1 to two years old on Jan. 1, 1959.) The following least-squares relation was then obtained:

$$R23_t = -3,197.0 + 1.036^{**}\ FIBCN_{t-1} - 1,103^{**}W.$$
$$(0.032)\qquad\qquad (50.0)$$
$$R^2 = 0.995\qquad\text{(Eq. 3.2)}$$

Since R23 has negative values, the negative intercept term includes the portion of cow slaughter not federally inspected, plus death loss and any other discrepancies arising from fewer heifers being held for the cow herd. The final form of the behavioral relation for estimation of Jan. 1 beef-cow inventories is:

$$H23_t = H23_{t-1} + H22_{t-1} - 3,197.0 + 1.036\ FIBCN_{t-1}$$
$$- 1,103\ W,\ \text{(Eq. 3.3)}$$

where W is given a value of 1 in 1960 and future years.

Under the initial assumption of a 14-percent average beef-cow culling rate (of the Jan. 1 inventory) during 1955-64 and approximately 60 percent of cow slaughter occurring under federal inspection, a quantity equal to 8.4 percent of the Jan. 1 beef-cow inventory (H23) was subtracted from the synthesized federally inspected slaughter variable. Graphic analysis revealed that the feeder-calf price during the year and trend were the relevant explanatory variables associated with the residual. Thus, the "fitted" portion of the estimator became,

$$\text{Residual } FIBCN_t = 4,316.0 - 125.9^{**}\ P2FC_t -$$
$$(15.0)$$
$$210.6^{**}\ T,$$
$$(25.0)$$
$$R^2 = 0.980\qquad\text{(Eq. 3.4)}$$

with the resulting behavioral relation being,

$$FIBCN_t = 4,316.0 + 0.08410\ H23_t - 125.9\ P2FC_t$$
$$- 210.6T.$$
$$\text{(Eq. 3.5)}$$

The negative sign on the current feeder-calf price is consistent with a feeder price that would result in a lower cull rate of cows intended for slaughter. The trend variable has a negative sign, not only because of reduced cow slaughter during the upswing of the cycle (during the latter part of the period covered), but also because of a lower percentage of slaughter occurring under federal inspection. The estimate, on a head basis, is not needed until the end of the year. The recursive nature of the system is thereby maintained. Since the estimate of federally inspected cow slaughter on a liveweight basis is an ex-ante relationship (a function of different lagged variables), consistency between the two should not be expected.

Commercial cattle slaughter

Commercial slaughter on a liveweight basis is made up of cull breeding stock and fed and nonfed younger animals. Furthermore, variations in commercial slaughter from year to year are associated with a sales response to a lagged price and to variations in the average weight of marketings. By using the coefficient associated with steer and bull inventories from the former model, the average ratio of estimated dairy-cow slaughter to Jan. 1 dairy-cow inventories, and the average ratio of estimated beef-cow slaughter to Jan. 1 beef-cow inventories, part of commercial slaughter can be assigned to these three variables. The resulting residual, which contains both a positive and a negative value, can be fitted to explanatory variables by least squares. Subtraction of the specific components of slaughter from reported commercial slaughter to obtain the residuals for each half-year can be accomplished with the following two equations:

$$R21_t = CS21_t - 0.1125\ H13_t - 0.0630\ H23_t - 0.5500$$
$$H24_t,\ \text{(Eq. 3.6)}$$

and

$$R22_t = CS22_t - 0.1125\ H13_t - 0.0770\ H23_t - 0.5000$$
$$H24_t. \quad (Eq.\ 3.7)$$

In equations 3.6 and 3.7, R21 and R22 denote the residual commercial slaughter (CS2j) for the January-June and July-December periods in millions of pounds liveweight. The coefficient of dairy-cow inventories (H13) is based on the 22.5-percent slaughter rate with that of beef cows based on the 14-percent slaughter rate. Fifty-five percent of the beef-cow coefficient is allocated to the second half of the year on the basis of the seasonal pattern of cow slaughter. Although the total coefficient associated with the steer and bull inventory is based on the coefficient in the second-difference equation, the first 6 months is favored slightly on the basis of past seasonal patterns of steer slaughter. The residual regression equations are:

$$R21_t = -3,460.0 + 295.9^{**}\ P2LFS_{t-2} - 0.8592\ \triangle$$
$$(59.6) \qquad\qquad (0.3510)$$
$$H13_{t+1} - 2.530^{**}\ NW21_t,$$
$$(0.693)$$
$$R^2 = 0.885 \qquad (Eq.\ 3.8)$$

and

$$R22_t = -2,645.0 + 236.5^{**}\ P2LFS_{t-2} - 1.005^{**}\ \triangle$$
$$(19.9) \qquad\qquad (0.201)$$
$$H13_{t+1} - 1.168^{**}\ NW22_t.$$
$$(0.100)$$
$$R^2 = 0.974 \qquad (Eq.\ 3.9)$$

Before discussing the coefficients obtained, the variable NW2j, needs to be explained. Briefly, it is a normalized value of the average weight of steers slaughtered under federal inspection. The average slaughter weight of steers slaughtered under federal inspection is multiplied by the ratio of (a) that portion of commercial slaughter assigned to steer and bull inventories (0.55 H24 or 0.50 H24) and (b) that portion of commercial slaughter assigned to dairy and beef-cow inventories (0.1125 H13, plus either 0.063 H23 or 0.0077 H23) for each period. Since this ratio ranges from 1.2 to 1.9, the resulting product of the ratio and average slaughter weight is normalized through multiplication by the ratio of the sum of the average slaughter weights divided by the sum of the products of average slaughter weights and the ratios of steer slaughter to cow slaughter.

The variable P2LFS is the average price of choice slaughter steers at Chicago computed on a July-to-June basis. Through prior graphic analysis of the residual, the July-to-June price appears as the relevant price variable for the residual component of the slaughter. It follows logically that the average price over the 12 months prior to the summer breeding season influences decisions on the number of cows to breed. The calves born the following spring are not slaughtered until the year $t + 2$. The forward first difference of dairy-cow numbers ($H13_{t+1}$) takes into account the change in

the slaughter rate from the average rate. With its negative coefficient, a larger-than-average reduction of dairy-cow numbers during the year results in an increased commercial cattle slaughter, whereas an increase in dairy-cow numbers reduces cattle slaughter. Steer weights are weighted by their slaughter share to allow for an appropriate share of total slaughter. The negative coefficient supports the hypothesis that, under normal conditions and behavior, steers are fed to heavier weights when cattle numbers (and slaughter) are relatively low. This model gives extremely accurate estimates over the historical period. The final combined commercial slaughter equations are:

$$CS21_t = 0.1125\ H13_t + 0.0630\ H23_t + 0.5500\ H24_t$$
$$+ 295.9\ P2LFS_{t-2} - 0.8592\ \triangle\ H13_{t+1} - 2.530\ NW21_t$$
$$- 3,460.0, \quad (Eq.\ 3.10)$$

and

$$CS22_t = 0.1125\ H13_t + 0.0770\ H23_t + 0.5000\ H24_t$$
$$+ 236.5\ P2LFS_{t-2} - 1.005\ \triangle\ H13_{t+1} - 1.168\ NW22_t$$
$$- 2,645.0. \quad (Eq.\ 3.11)$$

Inventories of dairy cows Jan. 1 (H13) are a function of milk consumption and productivity per cow. Per-capita milk consumption is a function of its own price, per-capita disposable income (both in 1957-59 dollars) and a trend term representing a shift in consumer tastes (19). Productivity per cow is adequately described by a growth, or logistic curve. Since dairy-cow inventories may be determined by variables all exogenous to the model, these inventories are treated as an exogenous variable during the historical period; its method of projection is presented later.

The revised model of commercial cattle slaughter requires a behavioral relationship for prediction of average weight of steers slaughtered under federal inspection (AWFSj). This relationship is postulated as a function of the beef-corn ratio lagged one period, the first difference of the preceding Jan. 1 steer numbers, and a trend component, as follows:

$$AWFSj_t = 928.0 + 5.296^{**}\ \left(\frac{P2jL}{P6j}\right)_{t-1} + 3.047^{**}\ Tj +$$
$$(1.541) \qquad\qquad\qquad (1.022)$$
$$0.01652\ \triangle\ H24_t.$$
$$(0.00600)$$
$$R^2 = 0.896 \qquad (Eq.\ 3.12)$$

A high beef-corn ratio encourages feeding to heavier weights, indicated by the price-quantity coefficient of 5.296. The trend component indicates an increase in fed cattle slaughtered in relation to total steer slaughter. The positive sign of the first-difference coefficient is not inconsistent with the earlier finding that slaughter weight decreases as cattle slaughter increases (particularly, since steer numbers are a stock rather than a flow variable and also represent only one component of total cattle numbers).

Feeder-calf prices

The coefficients associated with the variables of (a) fall feeder price and (b) change in numbers of cattle on feed are assigned values approximately equal to those of the same variables in the least-squares equation. The coefficient associated with the April-May range condition is assigned a value suggested by inspection of the residual. The final synthesized equation for estimation of feeder-calf prices in the spring is:

$$P21FC_t = -19.55 + 1.10 \ P22FC_{t-1} - 0.004 \triangle H26_t$$
$$+ \ 0.25 \ AMRGE_t.$$
$$\text{(Eq. 3.13)}$$

The spring feeder price is based essentially on the fall feeder price, except that an increase in cattle on feed the first of the year depresses prices. Similarly, above-average range conditions in the spring increase the demand for light calves to be placed on pasture.

The fall-feeder-price estimate obtained by using data from the 1955-62 period is based on successive analysis of residuals. Two equations were developed. The appropriate equation to use depends on whether or not the current live-steer price is $1.25 or more below the preceding fall price at the Chicago market; if it is below the prescribed limit, then the estimating equation for fall-feeder-calf price becomes, $P22FC_t = 1.25 \ P22L_t + 0.20 \ RANGE_t + 0.50 \ PM - 33.50.$ (Eq. 3.14)

The coefficient on live price in equation 3.14 is greater than 1 because of the higher potential value of the feeder animal. Above-average range conditions in the early fall (i.e., Oct. 1) in the 17 western states enable ranchers to wait for higher bids by feeder buyers, thus supporting feeder prices.

The variable PM represents the price margin in feeding calves the preceding January-June period. The feeding margin is estimated by the equation, $PM = 1.615 \ P21L_t - 0.615 \ P21FC_{t-1}.$ (Eq. 3.15)

The price margin is based on a 400-pound calf fed to a 1,050-pound Choice steer in 360 days. When live price exceeds that of the year before, cattle feeders are likely to consider the price margin during the first half of the year in buying feeders. If the current live price falls below that of the previous fall by more than $1.25, cattle feeders, being more price conscious, look at the current price margin, but they attach a somewhat lower weight to the price margin and a higher weight to the steer price. In this case, the price margin relation is, $PM = 1.615 \ P22L_t - 0.615 \ P22FC_{t-1},$ (Eq. 3.16) and the fall-feeder-price relation is, $P22FC_t = 1.5 \ P22L_t + 0.4 \ PM + 0.2 \ RANGE_t - 37.00.$ (Eq. 3.17)

Nonlinearities and Discontinuities

The early simulation runs also revealed the possibility of obtaining more accurate predictions of the

historical period by separating the behavioral relationship into two or more segments. For example, high prices lead to expectations that supplies are building up too fast, thus resulting in a smaller response to price. Similarly, low prices lead to expectations that supplies will soon be short. Also, there may be other limitations to the linear rate of response to price (e.g., ranchers try to maintain a minimum basic breeding herd in times of severe drought). This type of nonlinearity may be verified through successive changes in the value of the coefficient during several consecutive simulation runs — a procedure that is quite easy to introduce in computer language. This refinement in behavioral relations is used in five different equations in the model.

Foreign trade in beef

Only one nonlinear relationship is introduced in the foreign-trade equation for beef. The coefficient estimated by least-squares procedures for the lagged wholesale price of beef is 8.6. If the wholesale price falls below $38 per 100 pounds, the coefficient is reduced to 6.0. At the lower price level, importers are expected to respond differently than at higher prices; exporters also are able to compete in foreign markets at the lower price.

Wholesale price of beef

The wholesale price of beef is for Choice carcasses. Initially, this price appears to explain the combined effect of all grade differentials on per-capita consumption. When transposed to a price-dependent basis, the per-capita consumption variable is associated with plausible price changes only as long as a certain quality composition of beef is maintained. However, during the peaks and troughs of the cattle cycle, cow-beef makes up a larger percentage of per-capita beef consumption. This quality change tends to reduce the price sharply.

To simplify the behavioral relation, the per-capita consumption effect is assumed to involve a shift of the entire relation in the consumption plane. Therefore, a particular ratio of federally inspected cow slaughter to commercial cattle slaughter is formed as a decision rule. If this ratio exceeds 0.25, $1 is added to the constant term of the equation. If the ratio is below 0.16, $1 is subtracted from the constant term of the equation.

Sows farrowing in the fall

Although fall farrowings essentially are determined by the level of farrowings in the spring, the corn-hog ratio and a trend component, the relative expectations of profitability of the hog versus the beef enterprise are important. If the hog enterprise appears to offer a greater chance of profit, the pro-

ducer may breed more sows for fall pigs and cut the number of cattle he puts on feed that fall. Usually the ratio of live hog to steer prices is about 0.65. Therefore, if the ratio of hog price to steer price the first half of the year (P31L/P21L) exceeds 0.75 (indicating current favorability of the hog enterprise), the intercept in the sows-farrowing relationship is increased by 200,000 head. Conversely, when the ratio is less than 0.50, 200,000 head is subtracted from the average intercept level.

January 1 inventories

The annual average feeder-calf price and the average annual slaughter-steer price in the preceding year affect the various categories of cattle inventory. In the beef-heifer relation, a $1 increase in the average steer price results in a 142,000-head increase in beef heifers held on farms the following Jan. 1. In the revised relation, however, if the price falls below $23 or exceeds $28, the change in beef-heifer numbers falls to 135,000 head for each $1 change.

The average feeder-calf price affects the number of calves under 1 year of age, steers and bulls over 1 year of age, and cattle on feed Jan. 1. The inventory response to feeder price near the mean value of $25-$26 is 166,000 head for calves, 81,000 head for steers and bulls, and 71,000 head for cattle on feed. However, if feeder-calf prices fall below $22 or exceed $35, producers' reaction to holding young calves is reduced slightly to 155,000 head per dollar change in feeder price. At prices less than $22, the inventory-price coefficient for steers and bulls on hand Jan. 1 is reduced to 70,000 head, if the price is falling, but is increased to 95,000 head, if feeder-calf prices are low but rising. When the feeder price exceeds $35, the number of steers and bulls is increased to 95,000 head per dollar change in feeder price. More than half of the steers in the Jan. 1 inventory are not on feed. Thus, if prices are low and falling, producers expect a lower demand for feeders and hold fewer yearlings for feedlot replacement, but if prices are either low and rising, or high, a greater demand for feeder animals is indicated.

In the case of cattle on feed, the inventory response is reduced slightly to 65,000 head when the feeder price falls below $24.50. When the feeder price exceeds $35, the inventory response of cattle on feed is reduced to 60,000 head per dollar change in feeder price. Thus, the reaction in cattle on feed takes the opposite direction of that portion of steers over 1 year of age not on feed.

Sow and gilt inventories are increased by 252,000 head for each $1 increase in the corn-hog ratio in the previous year. However, if the ratio falls below 11 or rises above 20, the inventory response falls slightly to 240,000 head. In the case of the unfavorable corn-hog ratio, less breeding stock is held because of the anticipated continuation of unprofitable prices. When the ratio is extremely high, pro-

ducers do not expect the favorable relation to continue.

Limiting Values

A priori knowledge of the livestock-meat economy is the basis for the minimum and maximum values on certain endogenous variables in the economic model. For example, it is known that the marketing channels require a certain minimum amount of meat, below which ending stocks do not fall. Also, with the exception of net foreign trade, negative values of any of the endogenous variables are illogical. This limit to minimum values is applied in two relationships of the model. If ending stocks of beef are predicted to be below 100 million pounds (designated as the minimum amount needed for normal trade), these stocks are set at 100 million pounds. This type of problem did not arise in the pork sector, so a similar limit does not exist for pork stocks.

Sows farrowing in the fall have never exceeded spring farrowings. Therefore, if the fall estimate exceeds the spring estimate, it is set equal to the spring farrowing estimate. This situation did arise once near the end of simulation of the historical period.

ALTERNATIVE MARKET STRUCTURES AND STRATEGIES

The brief introductory discussion of marketing policy goals offers a point of departure for a more detailed examination of alternative market structures and strategies. The different market structures presented are associated with different market strategies. Each of the market strategies, in turn, is associated with a unique set of market relationships and variables. The latter are summarized in terms of wholesale-to-retail margins, foreign-trade limitations and price stabilization.

Wholesale-to-Retail Margins

Meat-packing and wholesaling businesses may follow a variety of margin policies which can be summarized as a fixed markup (over cost), a variable markup or a semivariable markup. In the latter policy, the wholesale-to-retail margin is a function of the wholesale price and a constant term that does not vary with changes in price or quantity.

Each of the margin policies, for the purpose of this report, must be interpreted in an aggregate sense rather than as a decision strategy for a particular business enterprise. Thus, in the case of the semivariable markup, part of the retail firms could follow a fixed markup policy while the remainder follow a variable markup policy, or all retail firms could follow a markup policy in which a portion of margin is fixed and the rest varies with wholesale

price, or a combination of the two situations might occur.

In terms of market organization, a fixed markup policy can exist in a fragmented retailing industry in which each small establishment caters to a local neighborhood market. In this case, the retailer most likely is an oligopolist in the area he serves. He would also have a differentiated product by virtue of specialized retailing services. On the other hand, a retailing industry tending toward a smaller number of large firms with many retail outlets could favor a variable or semivariable margin strategy because of the application of machine-accounting procedures and the occurrence of many prepackaged products; presumably, the use of a fixed margin on each item would be unlikely. It is conceivable that any of the three margin strategies could be followed, depending upon the organization of the retailing industry.[4]

Time-series data show that, over 1955-64, the wholesale-to-retail margin at Chicago averaged 38 percent of the wholesale price, or $16 per hundredweight in absolute terms. The $16 fixed markup is entered in the case of the fixed-margin strategy which, when adjusted by the consumer price index, results in a range in the wholesale-to-retail margin of $15.68 to $23.60. Further, a 38 percent markup is used for the variable markup margin. Finally, the semivariable markup is made up of a fixed component of $8 dollars and a variable component that is 0.19 times the wholesale price.

Foreign Trade Limitations

Producer concern over increased imports of beef could lead to restrictive legislation. Thus, the computer model was adjusted to allow for two types of import restriction. One type of control involves limiting net imports of beef to a percentage of current domestic beef production. Another form of control places an absolute limit on net imports.

The two alternative trade strategies can be traced out by only slight modification of the computer model. For example, the percentage-control model is simulated for both the historical and projection periods by placing an upper limit on the net foreign trade in beef, the limit being 4 percent of current beef production.

Cattle producers have suggested limiting imports of beef to the average of the 1958-62 period. Simply for purposes of simulating the effects of a limitation of an import quota, an arbitrarily placed limit of 488 million pounds is placed on the net foreign imports of beef. This quantity is the average net foreign trade in beef on a semiannual basis during the 5-year period 1958-62. It should be emphasized, again, that neither the percentage quota nor the absolute quota are offered as solutions to the price-depressing effects

of increases in beef imports. Nor are the import quotas used in the computer model based on comprehensive studies of foreign supplies of beef covering the projection period.

Price Stabilization

A price-stabilization program might work as follows: A target level of per-capita consumption of beef and pork is established on the basis of recent market experience. No production controls are applied, however. Production in excess of domestic requirements is sold on the world market. Imports occur only during periods of deficit domestic production. Wholesale meat prices for domestic use are guaranteed, but export meat is sold at specified world prices. Under this arrangement, retail margins remain fixed.

Under the price-stabilization alternative, per-capita consumption of beef and pork and a guaranteed domestic price are set at the average levels for the 1955-64 period, with the price varying with the consumer price index. During this period, the average per-capita consumption of beef is 41.5 pounds on a semiannual basis, while average per-capita pork consumption is 30 pounds. The average wholesale price of both beef and pork at Chicago is about $42 during the historical period.

In addition, imports do not affect the domestic price under the price-stabilization alternative. However, exports are sold at the Liverpool price. In this case, the wholesale price is a weighted average of that portion sold in the domestic market and that portion sold at Liverpool, minus a 6-cent ocean-freight rate and a 20-percent tariff. The postulated net export prices for both the historical and projection periods average about 45 percent to 50 percent of the domestic price.

In the experimental results, pork consumption remains at the 30-pound level per 6-month period for the entire projection period. However, per-capita consumption of beef is allowed to increase 1½ pounds per year. By 1975, the per-capita annual beef consumption reaches 100 pounds per person. These target estimates are based on the historical market structures.[5]

COMPUTER MODEL AND SIMULATION PROCEDURES

The behavioral relations developed in the previous chapters were rewritten in Fortran language for the IBM 7074 computer by using a block diagram of the economic structure (illustrated in figs.

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[4] Quantitatively, the so-called fixed-margin strategy is treated as an exogenous element. In the case of the variable and semivariable margins, a simultaneous, convergent loop-solution is obtained by the computer.

[5] Three strategies that might be employed by producers or processors simulated over the historical period are: producers withholding livestock from market for 30 days, an increase in the processor margin and a contract between producers and processors that covers one-third of all cattle and hog production. Inasmuch as the empirical results are inconclusive, these strategies are not included in this report.

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3 and 5) as a guide.[6] Briefly, the components of the two consumption identities, per-capita beef and pork consumption, for the second half of the year are calculated. The wholesale and derived live prices are then estimated as functions of consumption and exogenous variables. January 1 inventories of livestock are estimated next, followed by estimates of the January-June consumption components and resulting prices.

Simulation of the Historical Period

The 9-year period, July 1, 1955, to June 30, 1964, was chosen as the validation period. The lag variables specifying the initial conditions were less affected by the influence of World War II and the Korean conflict than in the preceding years. The period covers approximately one complete cattle cycle and two hog cycles. All lagged values of endogenous variables up to July 1, 1955, were read into the computer as initial conditions plus values of all exogenous variables for the 9-year period as shown in the economic structure.

The predicted values generated for the 43 endogenous variables at the national level, and the reported values, are presented in table 2. The predicted and reported values of each variable can be compared on a time-series basis by reading across the rows of the table. The sequential estimation of the value of each variable may be followed through the 9-year period by reading down each column commencing with the first column heading, July 1, 1955. Two statistical measures of the accuracy of the predictions are presented in Appendix A.

Operation of the Model as a Closed System

The model may be operated as a closed system by holding all values of the exogenous variables, including time, at their initial values; namely, the 1955 levels. The experiments that were performed illustrate the dynamic interaction of the endogenous components of the system in isolation.

The computer experiments were performed on a closed economy over a 15-year period. The time paths generated are presented for six selected variables: Jan. 1 beef-cow and sow and gilt numbers, commercial cattle and hog slaughter and wholesale prices of beef and pork. These six variables, which are graphed in figs. 6 and 7, and their interrelationships are the primary structural elements of the system.

A 4-year cycle for hogs and a 4- to 5-year cycle for cattle were generated by the endogenous mechanism of the simulated livestock-meat economy. The results show that the price-output mechanism
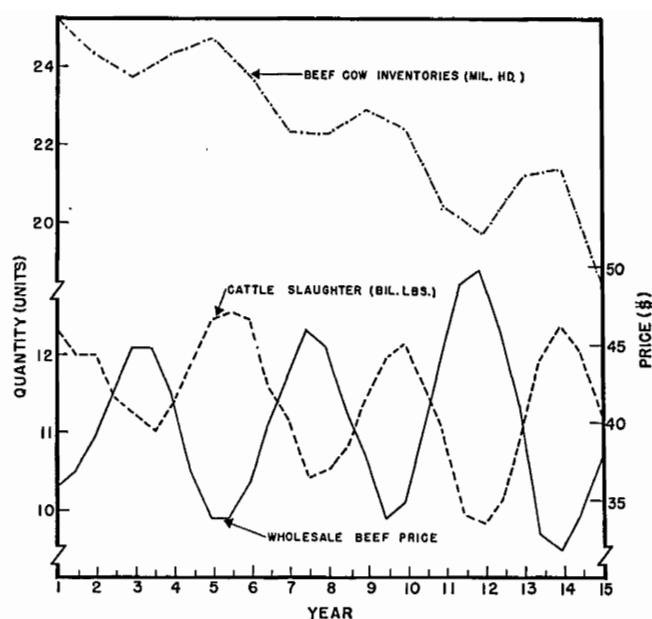
Fig. 6. Selected variables in the beef sector of closed system over a 15-year period.
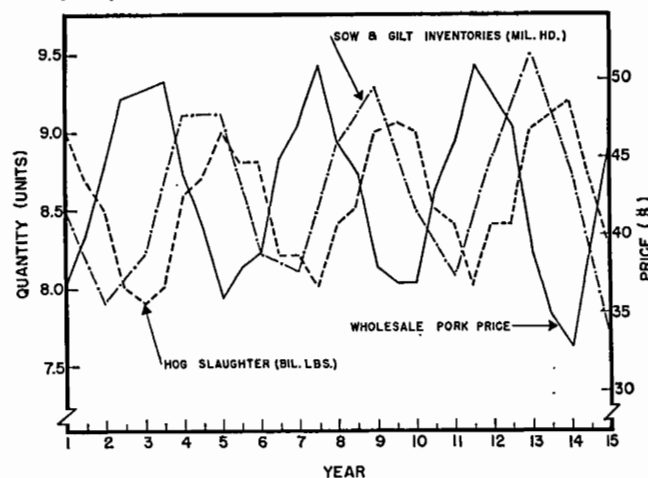
Fig. 7. Selected variables in the pork sector of closed system over a 15-year period.

tends to be self-correcting; i.e., an increase in inventories leads to an increase in commercial slaughter, thereby lowering prices and, eventually, inventories. After effects of lagged exogenous variables are overcome, irregular variations are eliminated. This results in the generation of "smooth" cyclical time paths. However, the slight increase in amplitude of succeeding production and price cycles reveals a slightly explosive tendency in the endogenous components.

Exogenous influences lengthen the cattle cycle more than the hog cycle. These exogenous effects also appear to hold the explosive elements of the endogenous components in check. For example, the negative and positive trends in consumer preferences for pork and beef could account for part of the tendency toward stability as could weather conditions and business cycles.

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[6] Writing the program on a July 1 to June 30 basis required conversion of subscript notation in the behavioral relationships presented in earlier chapters to the new 12-month period. A detailed copy of the program may be obtained from the authors.

Table 2. Predicted and reported price and output variables of the beef and pork sectors of the livestock-meat economy, United States, July 1, 1955, to June 30, 1964.

Variable[a]	Unit	Predicted or Reported	1955	1956	1957	1958	1959	1960	1961	1962	1963
CS3 (hog slaughter)	mil. lb.	P	9,237	8,921	8,594	8,933	9,631	9,020	9,167	9,621	9,976
		R	9,283	8,890	8,432	8,642	10,011	8,951	9,186	9,440	9,969
PP3 (pork production)	" "	P	5,248	5,100	4,947	5,145	5,531	5,229	5,326	5,584	5,989
		R	5,294	5,050	4,823	4,993	5,773	5,217	5,380	5,590	5,978
FTR3 (pork imports minus exports)	" "	P	−3	−13	14	39	33	29	45	46	43
		R	25	− 7	8	45	7	21	29	38	8
ES3 (pork ending stocks)	" "	P	379	290	233	234	253	195	200	219	226
		R	421	280	194	206	264	170	200	230	277
QPH3 (per-capita pork consumption)	lb.	P	31.5	30.4	28.9	29.5	31.5	29.8	29.2	30.3	31.1
		R	31.7	30.4	28.4	28.6	32.7	29.9	29.4	30.5	31.7
AWFS (average steer wt.)	"	P	1,019	1,028	1,020	1,073	1,089	1,090	1,093	1,099	1,097
		R	1,010	1,016	1,024	1,070	1,087	1,090	1,108	1,072	1,110
CS2 (cattle slaughter)	mil. lb.	P	12,675	13,014	13,019	11,940	12,307	12,841	13,334	13,309	14,014
		R	12,683	13,229	12,728	12,035	12,049	13,038	13,254	13,297	14,345
BP2 (beef production)	" "	P	6,895	7,128	7,193	6,716	6,963	7,293	7,604	7,654	8,070
		R	6,900	7,154	6,971	6,664	6,852	7,373	7,576	7,533	8,238
FTR2 (beef imports minus exports)	" "	P	161	79	131	371	452	450	699	753	761
		R	96	54	198	493	527	376	573	795	904
ES2 (beef ending stocks)	" "	P	186	151	154	228	224	217	216	220	232
		R	205	244	134	174	202	170	200	189	281
QPH2 (beef per-capita consumption)	lb.	P	41.6	42.0	42.0	39.3	40.9	42.2	44.5	44.2	46.1
		R	41.1	41.3	41.2	40.0	40.8	42.3	43.6	43.9	47.7
FIC2 (beef-cow slaughter)	mil. lb.	P	3,375	3,786	2,754	2.451	2,244	2,484	2,556	2,362	2,564
		R	3,610	3,814	3,211	2,268	1,848	2,218	1,958	2,397	2,309
PWB2 (wholesale beef price)	$	P	35.98	41.45	40.83	44.59	43.68	43.43	41.48	46.66	41.34
		R	37.34	41.50	41.77	44.08	43.94	42.94	40.24	46.04	40.73
P2L (steer price)	"	P	21.49	25.18	24.69	27.22	26.52	26.26	24.83	28.31	24.56
		R	21.84	24.64	25.26	26.74	27.06	25.56	24.52	28.84	23.90
P2FC (feeder-calf price)	"	P	19.60	20.35	25.94	33.75	29.03	26.07	25.67	30.89	23.71
		R	20.30	19.69	25.20	33.09	30.75	26.59	27.62	28.44	26.14
PWB3 (wholesale pork value)	"	P	36.47	42.90	45.48	43.50	38.70	46.23	45.83	42.37	39.19
		R	39.66	40.29	46.75	48.49	38.15	43.41	42.66	44.18	41.18
P3L (hog price)	"	P	14.41	17.93	19.29	18.06	15.16	19.31	18.90	16.75	14.75
		R	14.94	16.44	19.38	20.54	13.72	17.68	17.74	18.05	16.55
SF (sows farrowing)	1,000 head	P	5,513	5,268	5,007	5,635	6,197	5,691	6,021	6,230	6,199
		R	5,599	5,181	5,112	5,887	6,128	5,855	5,923	6,170	5,911
FIBC (beef-cow slaughter)	" "	P	3,655	3,552	3,007	1,753	1,449	1,759	1,766	1,379	1,436
		R	3,500	3,700	3,050	1,700	1,050	1,900	1,500	1,350	1,650
H21 (other calves)	" "	P	18,852	18,167	18,413	19,411	20,331	20,771	21,539	23,020	24,344
		R	18,869	18,405	18,275	19,407	20,425	20,705	22,050	23,330	24,417
H22 (other heifers)	" "	P	6,194	5,992	6,017	6,749	7,010	7,180	7,140	7,700	7,811
		R	6,206	5,926	5,903	6,557	7,036	7,069	7,333	7,909	8,313
H23 (other cows)	" "	P	25,190	24,507	24,187	25,191	26,139	27,027	28,077	29,488	31,400
		R	25,371	24,534	24,165	25,112	26,344	27,102	28,305	29,970	31,779
H24 (steers, bulls and stags)	" "	P	11,227	10,662	10,770	11,600	12,226	12,592	12,811	13,525	14,475
		R	11,245	10,704	10,871	11,538	12,250	12,684	12,764	13,876	14,325
H26 (cattle on feed)	" "	P	5,997	5,949	5,854	6,712	7,215	7,495	7,667	8,257	9,023
		R	5,929	6,122	5,898	6,601	7,173	7,645	7,865	8,896	8,750
H32 (sows and gilts)	" "	P	8,487	7,883	8,223	8.776	7,590	7,575	7,825	7,827	7,347
		R	8,506	8,064	8,103	8,819	7,531	7,808	7,816	8,027	n.a.
SF31 (sows farrowing)	" "	P	7,648	7,093	7,406	7,914	6,822	6,809	7,039	7,041	6,599
		R	7,655	7,194	7,281	7,996	6,790	7,029	7,020	7,027	6,600
CS31 (hog slaughter)	mil. lb.	P	9,162	8,466	8,053	9,034	9,941	9,016	9,563	10,064	10,245
		R	9,339	8,472	8,050	9,299	9,707	9,201	9,543	9,869	10,087
PP31 (pork production)	" "	P	5,218	4,871	4.673	5,208	5,704	5,236	5,543	5,826	5,940
		R	5,234	4,756	4,625	5,358	5,646	5,350	5,640	5,889	6,043
FTR31 (pork imports minus exports)	" "	P	−13	10	23	27	23	49	56	56	56
		R	20	− 8	30	36	26	19	46	11	−21
ES31 (pork ending stocks)	" "	P	369	270	240	310	339	242	285	302	291
		R	365	277	210	313	351	240	295	320	413
QPH31 (pork per-capita consumption)	lb.	P	31.0	28.6	26.8	29.0	31.2	28.6	29.6	30.7	31.0
		R	31.4	27.8	26.5	29.8	30.9	28.9	30.1	30.8	30.8
P21FC (feeder-calf price)	$	P	18.71	22.27	30.62	33.39	29.37	27.50	26.50	31.32	22.72
		R	19.44	21.52	30.26	34.55	29.16	27.91	26.95	27.90	21.43
AWFS1 (av. steer wt.)	lb.	P	1,024	1,032	1,051	1,080	1,087	1,095	1,091	1,120	1,109
		R	1,043	1,033	1,040	1,075	1,097	1,115	1,092	1,116	1,125
CS21 (cattle slaughter)	mil. lb.	P	12,561	12,517	11,150	11,601	12,295	12,803	12,695	13,149	13,251
		R	12,454	12,408	11,398	11,207	12,293	12,826	12,923	13,544	15,241
FIC21 (cow slaughter))	" "	P	2,493	2,467	2,250	1,728	1,876	2,072	1,976	2,023	1,560
		R	2,646	2,739	2,373	1,702	1,909	1,773	1,853	1,848	2,133
BP21 (beef production)	" "	P	6,870	6,910	6,288	6,578	6,988	7,306	7,315	7,605	7,719
		R	6,936	6,881	6,319	6,381	7,001	7,354	7,398	7,813	8,832
FTR21 (beef imports minus exports)	" "	P	83	123	252	348	393	400	659	756	723
		R	41	61	356	469	330	392	573	707	595
ES21 (beef ending stocks)	" "	P	124	106	100	174	190	188	159	183	153
		R	135	113	108	168	145	155	123	186	287
QPH21 (beef per-capita consumption)	lb.	P	41.5	41.3	37.5	39.0	40.8	42.0	43.0	44.3	44.5
		R	41.8	41.2	38.1	38.3	40.7	42.0	43.2	45.0	48.9
PWB21 (beef wholesale price)	$	P	34.52	37.24	46.90	46.51	44.16	42.52	43.77	41.44	41.39
		R	34.37	36.98	46.01	46.55	45.01	42.03	43.40	41.09	37.64
PWB31 (pork wholesale value)	"	P	34.86	43.10	50.27	44.47	39.37	42.81	40.06	35.42	35.61
		R	36.30	43.56	50.10	41.42	39.74	42.17	41.33	39.27	38.81
P21L (steer price))	"	P	20.39	22.21	28.82	28.48	26.77	25.55	26.33	24.63	24.53
		R	20.10	22.24	28.42	28.87	27.07	25.04	26.53	24.32	21.69
P31L (hog price)	"	P	13.31	17.93	21.95	18.47	15.36	17.17	15.41	12.58	12.55
		R	14.62	18.37	21.49	16.76	15.52	17.81	16.98	15.68	15.55

a Variables denoting annual estimates are shown symbolically without the element identifying the half-year period (as shown in table 1).

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By eliminating the effects of population growth and other exogenous trends, some insights can be gained about the effects of market organization on production and prices. During the 15-year operation of the closed system, for example, there is no apparent trend in hog production or prices. It is reasonable to expect, therefore, that hog production and prices tend to be stable, unless exogenous forces dislodge the system. The prices are in current dollars; however, this does not mean that output is stable only under a declining real-dollar price. Removal of the trend components also adjusts for inflationary influences.

Cattle inventories and slaughter declined when the exogenous effects were removed. No trend in price was evident. Cattle slaughter, however, did not show as much downward trend as did inventories. Since herd liquidation increased throughout the period, the slower decline in slaughter than in inventories is consistent. Thus, a positive trend in consumer taste and in purchasing power is necessary to sustain beef production at current levels. The time period over which the structural relationships were estimated results, therefore, in a system that depends on exogenous elements for rapid growth in total output.

Projected Exogenous Variables

The structure of the beef-pork economy that existed over the 1955-64 period is projected to 1975 (July 1, 1974, to June 30, 1975). The purpose of making the projections is to compare market performance under the historical and alternative market structures. In making these projections, the reported values of the endogenous variables prior to July 1, 1964, are considered initial data.

January 1 dairy-cow numbers are obtained by dividing projected milk consumption by the projected productivity per cow. Milk prices are fixed at 1964 levels in 1957-59 dollars. As a result, the projected dairy-cow inventories decline monotonically to 15 million head in 1975.

Corn prices at Chicago are fixed at near current levels. An annual average price of $1.20 is assumed for the projection period with a 10-cent seasonal variation. Since current dollars are used, the real price of the input declines with the price level. Stocks of corn on farms Jan. 1 remain constant.

The projected civilian population of 226.5 million for 1975 prepared by the Bureau of the Census is interpolated to obtain semiannual estimates for the intervening years through use of a logistic growth curve. Output per man-hour in the meat-packing industry, the Consumer Price Index, the retailing margins and per-capita disposable personal income are projected on the basis of their historical trends. The projected 1975 income of $2,900 per capita is somewhat lower than the corresponding estimate by the National Planning Association (12).

Inasmuch as the demand functions were estimated by using income in a form of deviation from trend, use of income projections that deviate from trend introduces an explosive element into the system. This element manifests itself in the form of a rapid, upward-sloping growth curve.

Military consumption of beef and pork remains near current levels (324 million pounds of beef and 188 million pounds of pork). October 1 and April-May range conditions in the 17 western states are projected at their mean values of 78 and 77, respectively.

Modifications of the Model

Some historical trends are modified on the basis of additional information. The trend coefficients in the wholesale beef and pork price equations, for example, are allowed to decline to 0 by 1975 on grounds that shifts in consumer preferences for beef and pork can be expected to stabilize by that time. Similarly, the trend coefficient in the fall sows-farrowing equation is reduced from 210 to 50 for the projection period inasmuch as fall farrowings are unlikely to exceed spring farrowings. Finally, the average weight of slaughter steers is allowed to decline by 5 pounds per year under the assumption that cattle feeders will market cattle at lighter weights in the future.

The initial simulation runs revealed a need for a lower limit on the annual estimate of federally inspected beef-cow slaughter equal to 5 percent of the Jan. 1 beef-cow inventory. During the historical period, the slaughter rate did not go below this level. Thus, the lower limit maintains an average cow slaughter over the period of projection consistent with biological limitations.

For the historical period, the reduction in Jan. 1 beef-cow inventories associated with nonfederally inspected slaughter of cows and death losses (of both heifers and cows) was incorporated in the constant term (see equation 3.3). When the simulated inventory levels exceed the reported levels of the 1955-64 period, however, the constant term is too small to cover nonfederally-inspected cow slaughter and death losses. It was assumed, therefore, that 60 percent of cow slaughter occurred under federal inspection.[7]

Fewer cows than steers are slaughtered under federal inspection, since only a small portion of cow beef is graded and a larger portion of cow beef moves in intrastate commerce to satisfy the needs of local processing plants. Moreover, during periods of increased cow slaughter, a higher percentage is slaughtered under federal inspection because more cow beef must move in interstate commerce.

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[7] During the historical period, data on nonfederally inspected cow slaughter are not available. In 1955 and 1960, federally inspected slaughter of all cattle was about 75 percent of commercial slaughter (55). This assumption points up the need for data on the components of federally inspected slaughter.

Equation 3.3, therefore, is modified as follows: If federally inspected beef-cow slaughter (FIBCN) is less than 2.2 million head, the coefficient of federally inspected beef-cow slaughter is set at 2.0 (assuming that only 50 percent of cow slaughter takes place under federal inspection). On the other hand, if federally inspected beef-cow slaughter is relatively large (over 3.3 million head), the coefficient on the federally inspected component is set at 1.67 (assuming 60 percent of cow slaughter takes place under federal inspection). If federally inspected cow slaughter falls between 2.2 and 3.3 million head, the coefficient in the inventory equation is set at 1.8 (assuming a federally inspected component of 55 percent). In addition, 8 percent of the Jan. 1 beef-cow inventory the year before is subtracted to account for death loss of cows and heifers, plus nonfederally inspected heifer slaughter.

The retailing margins are a function of wage rates and other exogenous influences and, also, of sales. The initial projections show per-capita pork consumption at about 30 pounds; however, per-capita beef consumption varies between 40 and 55 pounds. Therefore, the following procedure is used to induce some variation in the retailing margin for beef: If per-capita consumption falls between 47.5 and 50 pounds, the trend value of the retail margin is used. However, $2.50 is added (subtracted) for each 2.5-pound decrease (increase) in per-capita beef consumption above or below the 47.5- to 50-pound range. This decision rule is based on the retailing margins calculated for the historical period.

Projected Values of Selected Endogenous Variables

The experimental results for the projection period show two full hog cycles (see table 3). The cattle cycle, as measured by Jan. 1 beef-cow numbers, shows a 2-year decline followed by a build-up in numbers through 1975. However, the build-up occurs less rapidly after 3 years of sharp increases. For example, the increase in beef-cow inventories from Jan. 1, 1969, to Jan. 1, 1970, is less than 200,000 head as a result of a substantial increase in beef-cow slaughter.

Thus, the use of the model to make projections involves two additional steps. First, the exogenous variables must be either assumed or projected by independent means. Second, biological considerations and other information concerning functional relationships must be used to make the projections as realistic as possible. Finally, the constant term in the functional relationships based on the least-squares method contains the average effect of all excluded variables—an effect that must be adjusted for industry growth and technological change.

Table 3. Projected price and output variables of the beef and pork sectors of the livestock-meat economy, United States, July 1, 1964, to June 30, 1975.

Variables	Unit	Year Beginning July 1										
		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
July - December period:												
CS32 (hog slaughter)	mil. lb.	9,868	9,917	10,019	10,618	11,123	11,071	11,120	11,509	11,942	12,248	12,358
CS22 (cattle slaughter)	" "	15,007	14,097	13,474	13,433	15,168	15,803	15,639	15,748	17,366	18,368	19,009
FTR22 (beef imports minus exports)	" "	658	743	875	955	954	944	994	1,091	1,120	1,140	1,184
QPH32 (per-capita pork consumption)	lb.	30.6	29.7	29.6	30.9	31.8	31.2	30.8	31.3	31.8	32.1	31.9
QPH22 (per-capita beef consumption)	"	48.0	44.9	43.0	43.1	47.2	48.0	46.8	47.0	50.4	51.9	52.9
PWB22 (wholesale beef price)	$	37.74	40.56	46.57	47.63	42.97	47.49	49.03	50.71	51.11	50.00	53.15
PWB32 (wholesale pork value)	$	39.04	43.25	46.18	42.73	38.25	41.83	43.94	43.97	41.88	40.84	42.77
P22L (steer price)	$	22.01	23.88	27.95	28.61	25.32	28.37	29.36	30.44	30.65	29.81	31.91
P32L (hog price)	$	14.52	16.80	18.34	16.21	13.50	15.41	16.48	16.36	15.02	14.27	15.24
P22FC (feeder-calf price)	$	19.40	23.70	34.45	34.90	24.35	26.76	35.94	35.73	33.41	30.61	36.47
SF32 (sows farrowing)	1,000 head	5,861	5,746	5,926	6,243	6,259	6,105	6,158	6,369	6,528	6,546	6,544
January 1 inventories												
H21 (other calves)	" "	25,427	24,637	24,988	26,362	28,472	28,347	29,743	32,025	33,887	36,097	38,899
H22 (other heifers)	" "	7,740	8,444	8,900	8,637	8,989	10,009	9,783	10,324	11,143	11,593	12,574
H23 (other cows)	" "	30,912	29,883	30,782	32,733	33,719	33,898	35,979	37,826	39,863	42,320	44,871
H24 (steers and bulls)	" "	14,665	15,982	15,723	17,035	17,144	18,054	18,553	20,435	21,964	22,432	24,068
H26 (cattle on feed)	" "	9,209	9,849	10,043	9,992	11,210	11,769	12,355	12,741	14,007	15,503	16,836
H32 (sows and gilts)	" "	7,053	6,955	7,461	7,747	7,341	7,141	7,363	7,623	7,685	7,521	7,534
January - June period:												
SF31 (sows farrowing)	1,000 head	6,328	6,238	6,704	6,967	6,593	6,409	6,614	6,853	6,910	6,759	6,771
P21FC (feeder-calf price)	$	19.32	23.20	36.82	38.30	21.61	26.90	36.89	37.46	31.39	27.39	34.49
CS31 (commercial hog slaughter)	mil. lb.	9,881	9,669	9,894	10,511	10,762	10,519	10,602	10,962	11,325	11,465	11,479
CS21 (commercial cattle slaughter)	" "	13,794	12,315	12,264	14,052	14,946	14,509	14,552	16,195	17,142	17,916	18,383
FTR21 (beef imports minus exports)	" "	727	725	829	902	923	941	962	1,065	1,091	1,124	1,174
QPH21 (per-capita beef consumption)	lb.	45.3	40.7	40.9	44.8	46.7	45.3	44.9	48.2	49.9	51.1	51.8
QPH31 (per-capita pork consumption)	"	29.8	28.6	28.7	29.9	30.1	29.1	28.8	29.2	29.6	29.5	29.2
PWB21 (beef wholesale price)	$	39.04	47.99	49.56	41.99	44.02	49.17	49.38	50.39	47.65	50.24	52.14
PWB31 (pork wholesale value)	$	38.67	46.20	46.52	40.06	40.39	45.73	46.81	46.14	43.94	45.43	47.38
P21L (steer price)	$	22.83	28.93	29.94	24.65	25.97	29.46	29.53	30.15	28.19	29.90	31.14
P32L (hog price)	$	14.16	18.35	18.39	14.54	14.58	17.51	17.99	17.47	16.06	16.77	17.75

Variable	Unit	1955 - 63				1964 - 74			
		Hist. struc.	Variable margin	Semi-variable margin	Fixed margin	Hist. struc.	Variable margin	Semi-variable margin	Fixed margin
CS2j (cattle slaughter) _____	bil. lb.	12.7	12.6	12.5	12.4	15.4	16.7	16.8	15.8
CS3j (hog slaughter) _____	" "	9.2	9.2	9.2	9.2	10.9	11.1	11.2	10.7
SFj (sows farrowing) _____	mil. head	6.4	6.4	6.4	6.4	6.4	6.7	6.8	6.3
QPH2j (per-capita beef consumption) ____	lb.	42.0	41.8	41.6	41.3	46.9	50.0	50.1	47.3
QPH3j (per-capita pork consumption) ____	"	30.0	29.9	29.9	29.8	30.2	30.9	31.0	30.0
PWB2j (wholesale beef price) _____	cents	42.1	42.3	42.5	42.5	47.2	47.5	47.9	47.0
PWB3j (wholesale pork price) _____	"	41.5	41.8	41.8	41.7	43.2	43.5	43.6	43.3
P2jL (steer price) _____	"	25.4	25.5	25.7	25.7	28.1	28.2	28.6	28.0
P3jL (hog price) _____	"	16.6	16.8	16.8	16.8	16.2	16.3	16.3	16.2
P2jFC (feeder calf price) _____	"	26.5	26.6	27.1	27.4	30.4	30.3	31.1	29.8
RM2j (beef retailing margin) _____	"	15.6	15.9	16.1	16.4	23.2	18.0	17.1	22.0
RM3j (pork retailing margin) _____	"	16.0	15.9	15.9	16.4	20.9	16.5	16.3	22.0

EXPERIMENTS ON SIMULATED MARKET SYSTEMS

Fourteen of the endogenous variables in the national model will be used to present the simulated market performance under alternative conditions.

To keep the number of tables at a minimum, the time paths generated for each of the nine alternative models are presented in slightly different form from that in the preceding chapters. The margin experiments, for example, are in one group, while the foreign-trade and price-stabilization experiments are in a second group.

In addition, a series of charts is used to show the time paths of three different variables in the beef sector and in the pork sector under four different sets of market assumptions. Moreover, the experimental results are compared graphically later with reference to a single variable generated under alternative market assumptions.

Margin Experiments

The results obtained under the alternative mar-

ket conditions—variable, semivariable or fixed retail margins—are compared with the results for the historical period (figs. 8 through 13 and table 4). In addition, the margin relationships are varied in magnitude to allow for an examination of the effects of changes in the competitive position of retailers and processors. (In figs. 8 through 13, the light line depicts estimates under the historical structure, while the heavy line depicts estimates under the alternative market strategy.)

Alternative margin relations

The range in per-capita beef consumption from 1964 to 1975 is 14.2 pounds under the variable-margin assumption, 14.1 pounds under the semivariable-margin assumption, and 14.5 pounds under the fixed-margin assumption. In the case of per-capita pork consumption, the range over the 1964-75 period is 3.4 pounds under the variable-margin assumption, 3.7 pounds under the semivariable-margin assumption and 4.9 pounds under the fixed-margin assumption.
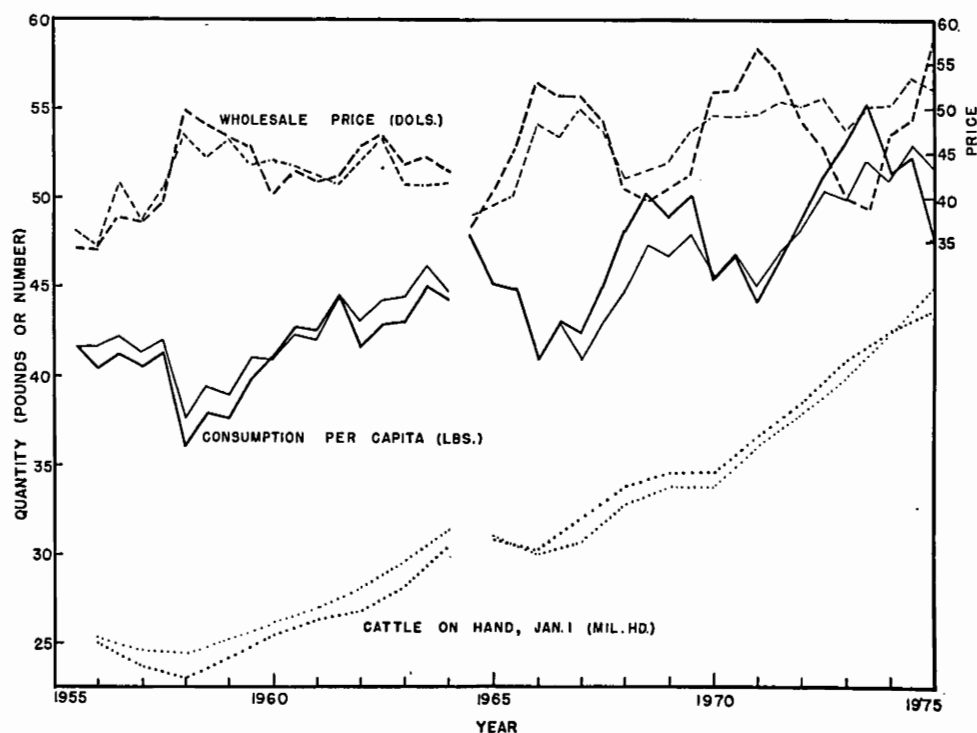

Fig. 8. Estimated per-capita beef consumption, wholesale price of Choice grade beef-steer carcasses at Chicago and beef cows on hand Jan. 1, fixed-margin experiment, United States, 1955-75.
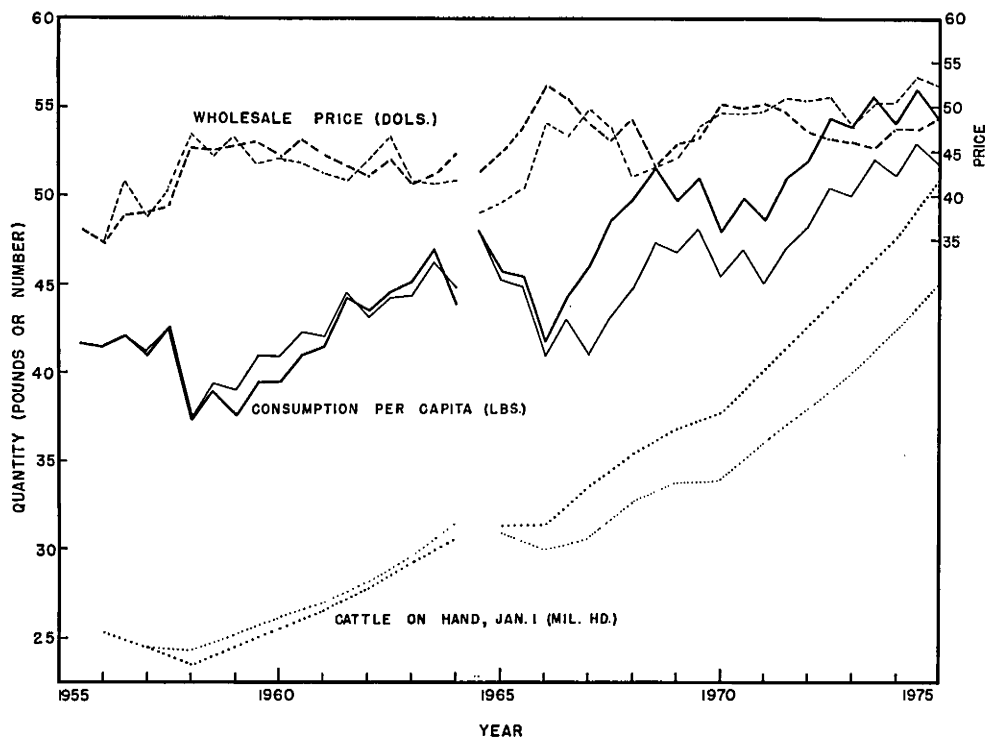
Fig. 9. Estimated per-capita beef consumption, wholesale price of Choice grade beef-steer carcasses at Chicago and beef cows on hand Jan. 1, variable-margin experiment, United States, 1955-75.
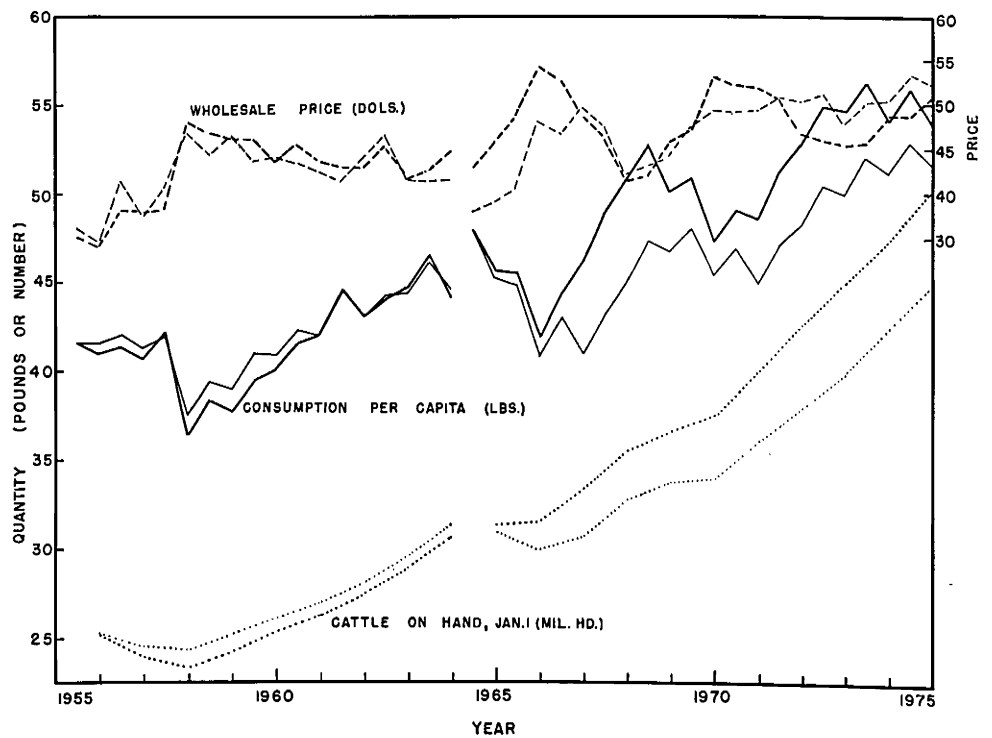

Fig. 10. Estimated per-capita beef consumption, wholesale price of Choice grade beef-steer carcasses at Chicago and beef cows on hand Jan. 1, semivariable-margin experiment, United States, 1955-75.

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Fig. 11. Estimated per-capita pork consumption, equivalent wholesale price of pork cuts at Chicago and sows farrowing, fixed-margin experiment, United States, 1955-75.
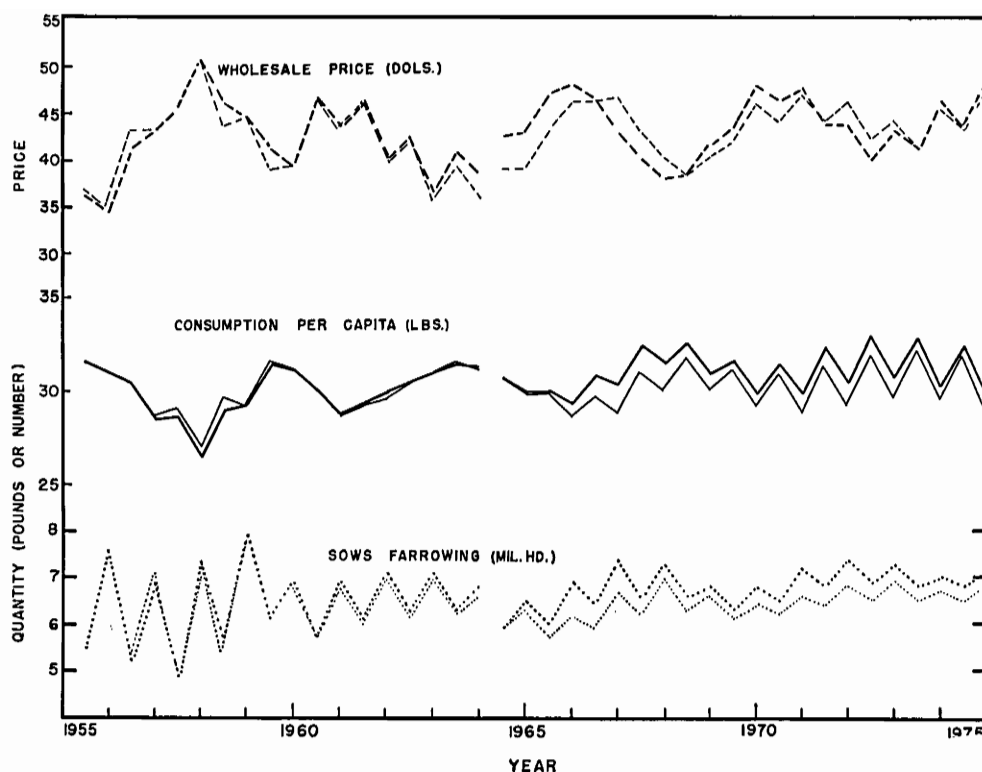
WHOLESALE PRICE (DOLS)

CONSUMPTION PER CAPITA (LBS.)

SOWS FARROWING (MIL. HD.)

PRICE

QUANTITY (POUNDS OR NUMBER)

YEAR

WHOLESALE PRICE (DOLS.)

PER CAPITA CONSUMPTION (LBS.)

SOWS FARROWING (MIL. HD.)

PRICE

QUANTITY (POUNDS OR NUMBER)

YEAR
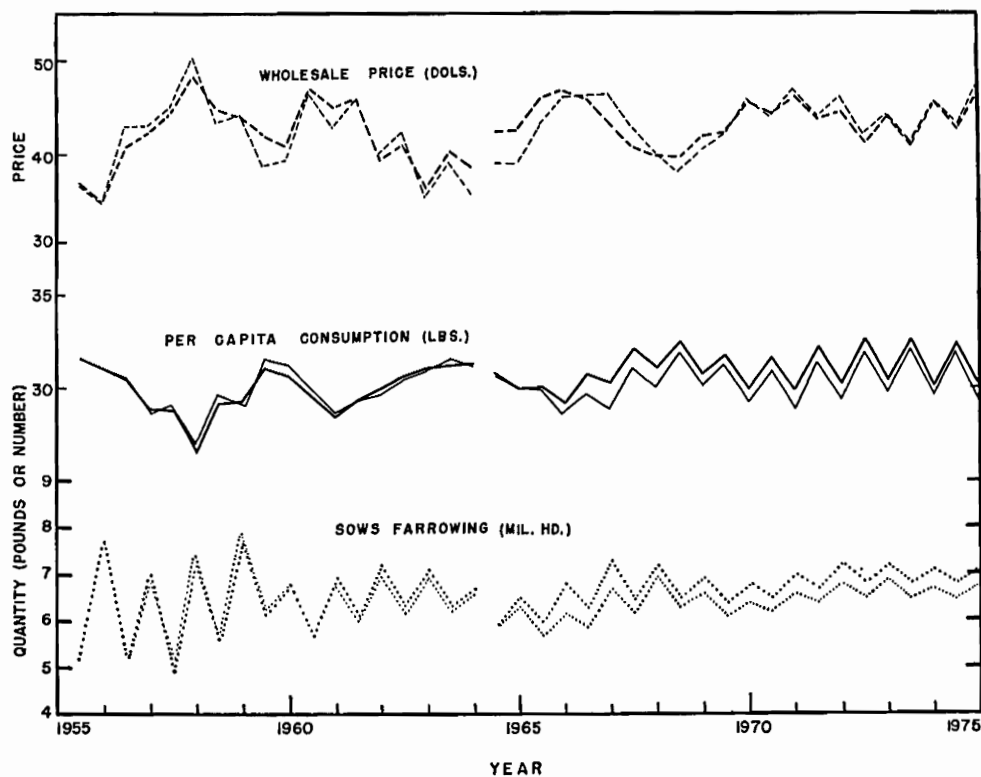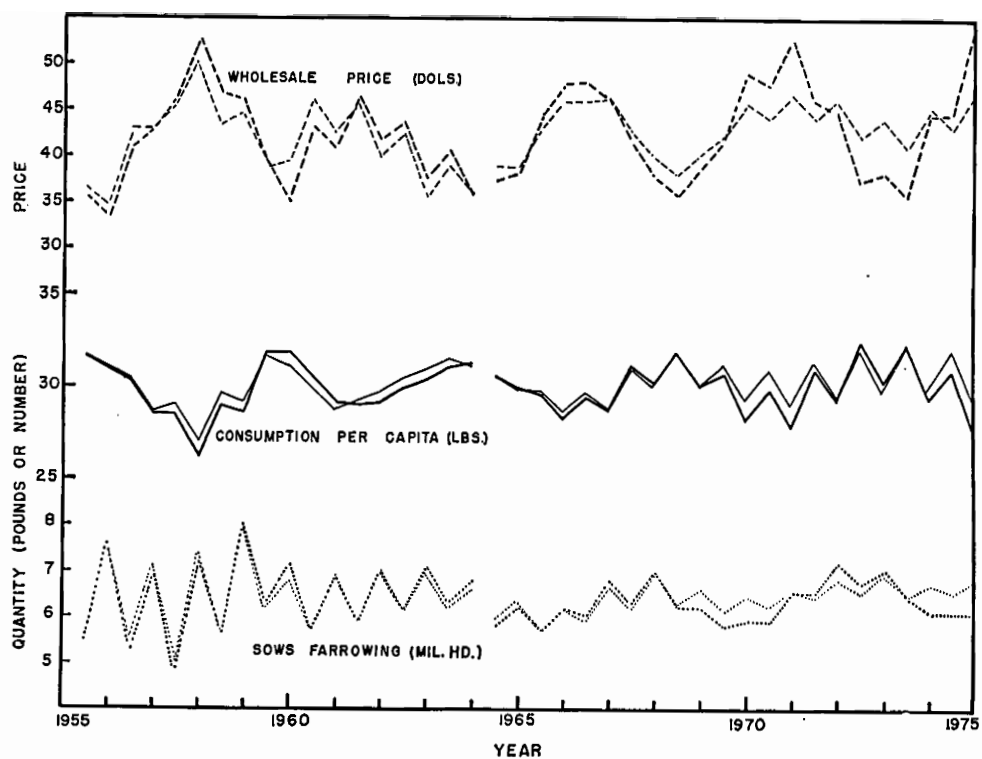
Fig. 12. Estimated per-capita pork consumption, equivalent wholesale price of pork cuts at Chicago and sows farrowing, variable-margin experiment, United States, 1955-75.

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Fig. 13. Estimated per-capita pork consumption, equivalent wholesale price of pork cuts at Chicago and sows farrowing, semivariable-margin experiment, United States, 1955-75.

The mean values of both wholesale and live-animal price in both the historical and projection periods are almost identical, but the range of variation is quite different. For the historical period, wholesale beef prices vary 10.9 cents per pound. For the variable-margin experiment, the range in beef prices is reduced to 10.5 cents. However, the semi-variable-margin and fixed-margin experiments show an increase in the range of wholesale beef price in the 1955-64 period of 13.7 cents per pound and 15.1 cents per pound, respectively.

The range in choice grade steer prices in the three experiments over the 1955-64 period follows the range in wholesale beef prices. This range in the variable-margin experiment is only 7.6 cents per pound during the 9-year period, compared with 10.8 cents in the fixed-margin experiment.

From 1955 to 1964, wholesale pork price varies by 15.4 cents under the historical structure, but in the variable-margin experiment this range is reduced to 13.5 cents per pound. However, in the semivariable and fixed-margin experiments, the range is increased to 16.5 cents and 19.3 cents per pound, respectively. Similarly, live-hog prices show a range of only 8 cents under the variable-margin experiment compared with an 11-cent range for the fixed-margin experiment.

In the projections to 1975, the mean values of the wholesale prices of beef and pork do not differ appreciably, given the form of the margin, but the range in wholesale prices during this 11-year projection period is even more pronounced than in the experiments over the historical period. Wholesale

beef price ranges from 9.8 cents in the variable-margin experiment, to 11.4 cents in the semivariable-margin experiment, and to 20.4 cents in the fixed-margin experiment. Choice steer price varies 6.6 cents per pound under the variable-margin assumption, whereas the range is 13.3 cents per pound under the fixed-margin assumption.

The range in wholesale pork price under the variable margin assumption is only 7.4 cents for the 1964 to 1975 projection, whereas the range under the fixed margin is increased to 18.5 cents. The range in live hog prices is also doubled by the fixed margin, the range being 4.5 cents per pound for the variable-margin assumption, compared with 9.6 cents per pound for the fixed-margin assumption.

Feeder-calf prices likewise show more variation under a fixed-margin than under a variable-margin structure in either simulation period. However, the average feeder calf price is about $1 higher during the historical period under the fixed margin than under the variable margin, whereas the average value is about $1 lower during the projection period under the fixed margin than under the semivariable margin.

Simulated Jan. 1 inventories of beef cows and steers decline more at the bottom of the last cycle in 1958 under the fixed margin than they did under the variable margin. The inventory levels increase at a somewhat slower rate under the fixed margin, but cow inventories were about the same in 1964 for each market experiment. In the projection period, the build-up in beef-cow numbers is 5-million head lower in the fixed-margin and historical simulations

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than in the variable-margin simulation. Likewise, the build-up in steer numbers is 3- to 4-million head lower in the experiments for the fixed-margin and existing-structure simulations in the projection period.

Total sow farrowings are 7 percent greater over the projection period under variable and semivariable margins than under the fixed margins. However, the range is about the same in all cases.

The mean values in the retailing margin experiments are about the same in the 1955-64 period. However, the range in the variable margin is approximately 4.5 cents in the case of both beef and pork as opposed to 2.25 cents for the fixed margin. In the projection period, the historical retail margin relation yields a 23-cent average margin for beef; the range is 9 cents. Mean values in the projection period for wholesale-to-retail margin for beef in the variable, semivariable and fixed-margin experiments are 18 cents, 17.1 cents and 22 cents, respectively, with ranges of 3.8 cents, 2.4 cents and 2.7 cents. The lower mean value in the case of the semivariable margin can be attributed to the lack of a changing price level in the estimation of the constant portion of the margin. Mean values for the pork retail margin in the historical, variable, semivariable and fixed-margin relations are, respectively, 20.9 cents, 16.5 cents, 16.5 cents and 22 cents, while the price ranges are 5 cents, 2.8 cents, 2 cents and 2.7 cents, respectively.

When all or part of the margin (variable or semivariable markup policy) is a percentage of the wholesale price, the absolute value of the margin likely will be lower than under a fixed margin when wholesale prices are relatively low (or vice versa). Therefore, the effect of the margin depends on the wholesale price level. Since per-capita supply is the main determinant of "own" price and since price varies inversely with quantity, the percentage margin enables a higher wholesale price to be realized during times of large supply, while the fixed margin tends to hold prices down during times of low supply. If beef supplies are plentiful when pork is in short supply (or vice versa), beef exerts more influence on the wholesale prices than pork does under the percentage markup (given the magnitude of the margin coefficients).

High prices generate inventory build-up which gives rise to increased slaughter and consumption. The price decline is tempered by the form of the margin according to the price level.

For example, during the historical period, the fixed margin averaged 16.4 cents per pound, while the wholesale beef price averaged 42.5 cents per pound. The percentage margin, calculated at mean wholesale price, was 16.1 cents per pound. Thus, when wholesale beef price exceeded 42.5 cents, the fixed margin restricted prices more than the variable margin, whereas the variable margin supported

prices relative to the fixed margin when supply and demand relations cropped prices below 42.5 cents. Finally, regardless of the form of the margin, a change in its absolute value had slightly more than twice the effect on beef price than on pork price.

Alternative margin levels

In addition to comparing experimental results for the four margin relations, the prices and outputs obtained for different levels of fixed and variable margins are presented in figs. 14 through 21. Each margin relation was simulated at two additional levels of wholesale-to-retail markup to establish the incidence of the assumed shift in margins.
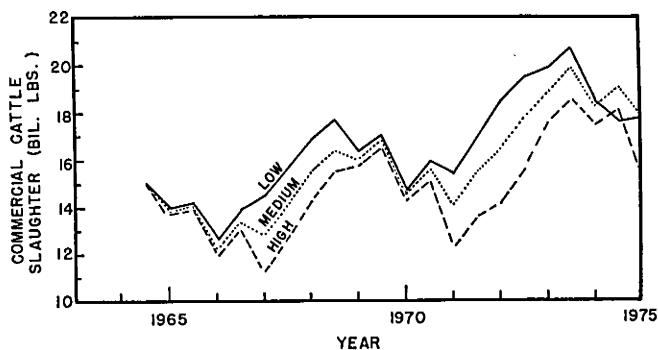
Fig. 14. Estimated commercial slaughter of beef cattle, in billion pounds liveweight, fixed-margin experiments, United States, 1965-75.
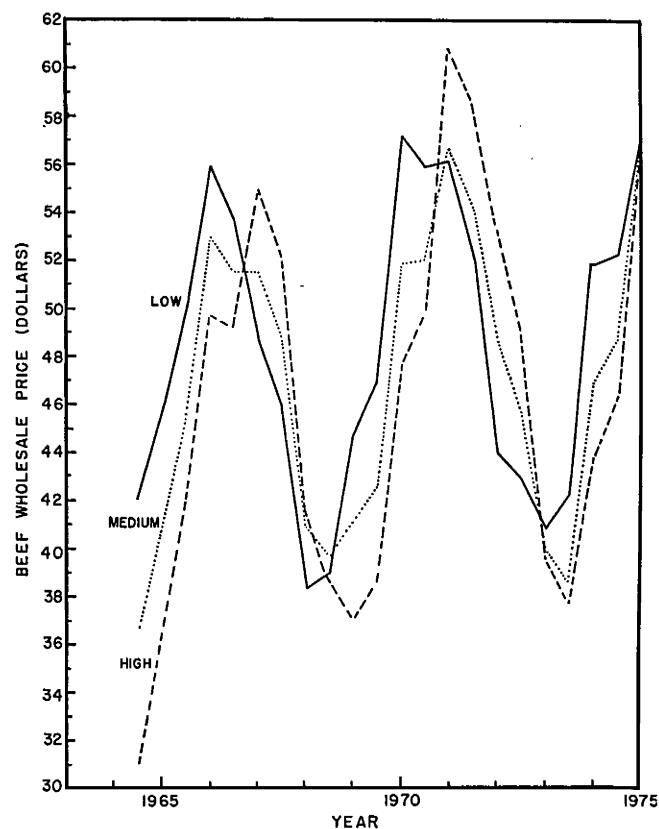
Fig. 15. Estimated wholesale price of Choice grade beef-steer carcasses, in cents per pound carcass weight, fixed-margin experiments, Chicago, 1965-75.

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During 1955-64, the average wholesale-to-retail margin was 16 cents. The two alternative levels are simulated by using a 4-cent increase and a 4-cent decrease—a 25-percent change. Thus, in the case of the variable markup, simulation runs using a 47.6-percent and a 28.6-percent markup are obtained

(along with the original 38-percent markup). In the case of the semivariable markup, 2 cents are allocated to the fixed portion of the markup, while the variable portion is set at 23.8 percent and 14.3 percent. In addition, the fixed portion of the markup is allowed to increase with the Consumer Price Index. In the case of the fixed-margin simulations, 4 cents are added or subtracted from the 18-cent average fixed markup in the projection of the historical margin relations. The fixed margin is adjusted by the projected Consumer Price Index for 1964-75.
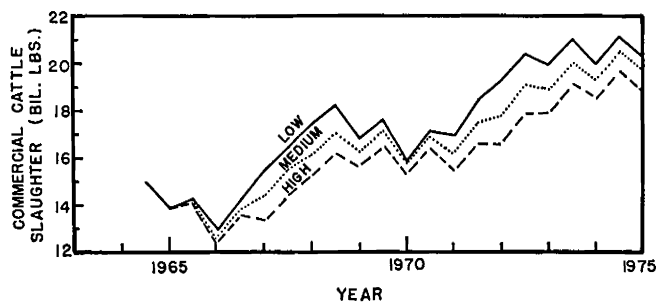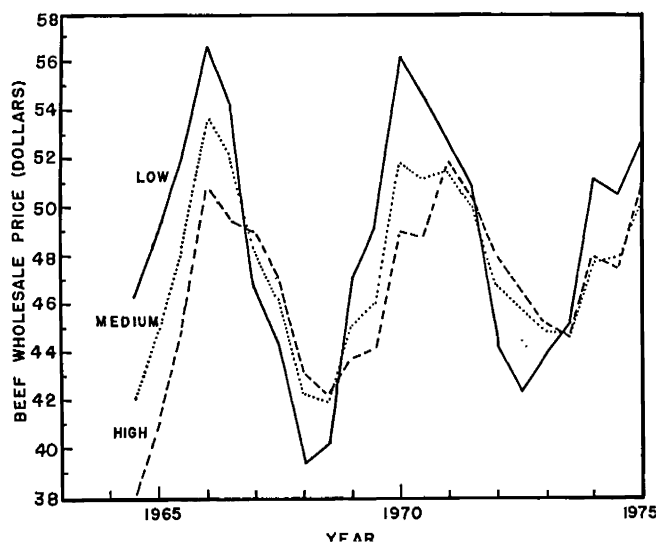

Fig. 16. Estimated commercial slaughter of beef cattle, in billion pounds liveweight, variable-margin experiments, United States, 1965-75.

Fig. 17. Estimated wholesale price of Choice grade beef-steer carcasses, in cents per pound carcass weight, variable-margin experiments, Chicago, 1965-75.
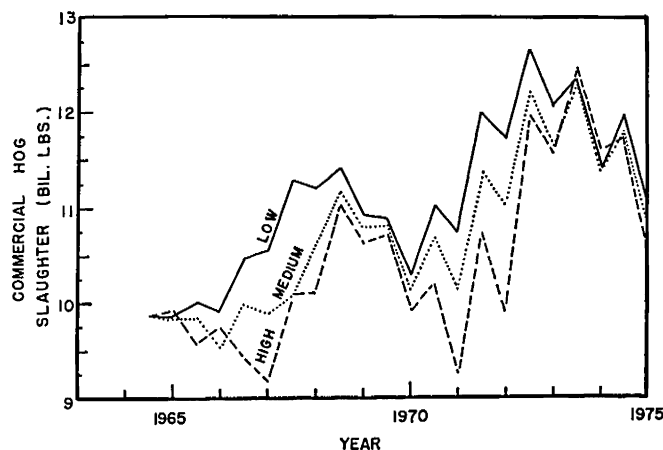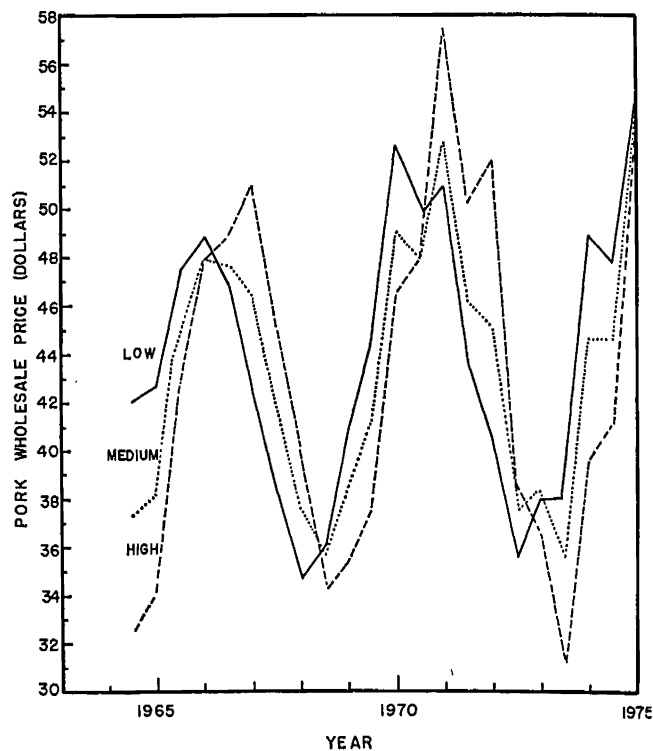

Fig. 19. Estimated equivalent wholesale price of pork cuts, in cents per pound carcass weight, fixed-margin experiments, Chicago, 1965-75.

Fig. 18. Estimated commercial slaughter of hogs, in billion pounds liveweight, fixed-margin experiments, 1965-75.
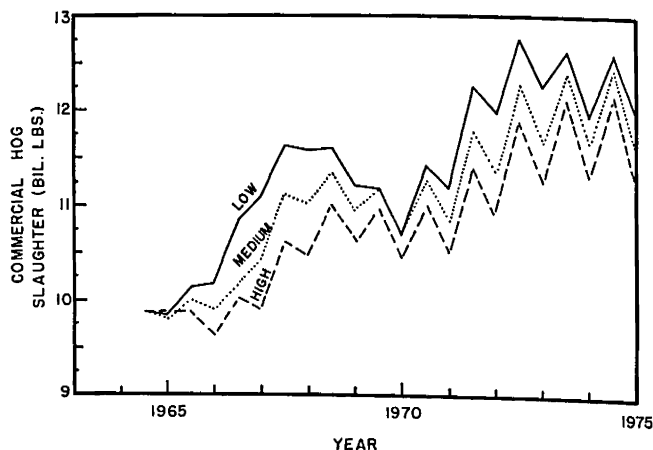

Fig. 20. Estimated commercial slaughter of hogs, in billion pounds liveweight, variable-margin experiments, United States, 1965-75.
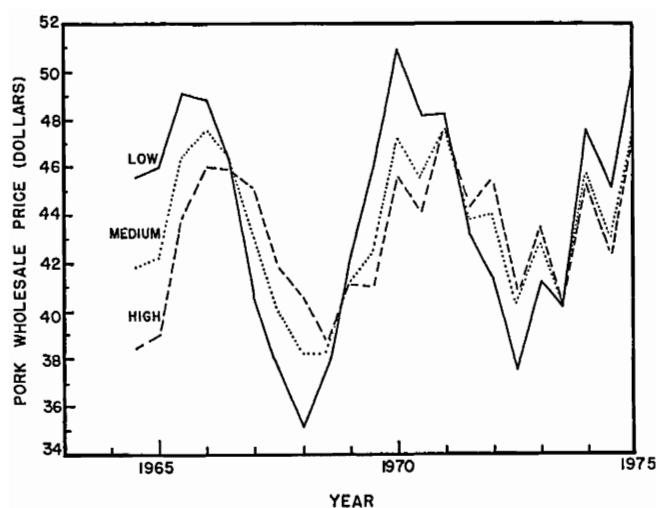
Fig. 21. Estimated equivalent wholesale price of pork cuts, in cents per pound carcass weight, variable-margin experiments, Chicago, 1965-75.

The average values of selected prices and outputs are shown in table 5. The average retail margin for beef increases or decreases about 4 cents over the 11-year projection period for the high or low levels of all three forms of the wholesale-to-retail margin. Approximately 3 cents of this change is accounted for by a change in the retail price, while the wholesale and live-animal price changes by approximately 1 cent. In the case of the change

in the level of the pork wholesale-to-retail margin, slightly more than 75 percent of the 4-cent change occurs in the retail price.

Higher margins reduce per-capita consumption, livestock inventories and slaughter. The output-reducing effect of the fixed margin as opposed to the variable margin is also evident in comparisons of the high, medium or low levels of each margin relation.

Trade and Price Stabilization Experiments

Computer experiments were performed for both the historical and projection periods, given specified limits on net imports of beef and alternative policies for price stabilization. The experimental results for the two forms and three levels of import restrictions are compared with each other as well as with those of the historical structure (table 6). The price-stabilization experiments, however, are compared only with the historical base.

Foreign trade restrictions

The limitation of 4 percent of domestic beef production on net foreign trade in beef becomes operative in the fall of 1958 in the historical simulation. Both the 4-percent restriction and the restriction of imports to the 1958-62 average become operative immediately in the projections and remain operative throughout that period. In the historical period, the

Table 5. Summary of estimated average semiannual levels of selected variables under different margin levels, United States, 1964-75.

Variable	Unit	Variable margin			Semivariable margin			Fixed margin		
		28.6 percent	38 percent	47.6 percent	6 cents and 14.3 percent	8 cents and 19 percent	10 cents and 23.8 percent	15 cents	19 cents	23 cents
CS2j (cattle slaughter)	mil. lb.	17.4	16.7	16.0	17.4	16.6	15.8	16.6	15.7	14.8
CS3j (hog slaughter)	" "	11.4	11.0	10.9	11.4	11.1	10.8	11.1	10.7	10.4
H23 (other cows, Jan. 1, 1975)	1,000 head	52.6	51.0	47.8	52.3	49.4	45.3	47.9	43.6	37.7
QPH2j (per-capita beef consumption)	lb.	51.6	50.0	48.3	51.5	49.8	47.9	49.7	47.3	45.4
QPH3j (per-capita pork consumption)	"	31.6	30.9	30.2	31.5	30.8	30.0	30.7	30.0	29.2
PR2j (retail beef price)	cents	62.3	65.5	68.4	62.5	65.8	69.3	65.8	69.0	72.9
RM2j (beef retailing margin)	"	13.8	18.0	22.0	13.9	18.3	22.6	17.4	22.0	26.7
PWB2j (wholesale beef price)	"	48.5	47.5	46.3	48.6	47.5	46.6	48.4	47.0	46.2
P2jL (steer price)	"	29.0	28.2	27.5	29.1	28.3	27.7	29.0	28.0	27.5
P2jFC (feeder-calf price)	"	31.7	30.3	29.3	31.8	30.6	29.7	31.3	29.8	28.6
PR3j (retail pork price)	"	56.4	60.0	63.3	57.2	60.9	64.9	61.3	65.3	69.6
RM3j (pork retailing margin)	"	12.5	16.5	20.0	13.2	17.5	21.8	17.4	22.0	26.7
PWB3j (wholesale pork value)	"	43.9	43.5	43.3	44.0	43.4	43.1	44.0	43.3	42.9
P3jL (hog price)	"	16.5	16.3	16.2	16.6	16.3	16.1	16.6	16.2	16.0

Table 6. Summary of estimated average semiannual price and output variables in selected trade and price-stabilization experiments, United States, 1955-75.

Variable	Unit	1955-64			1964-75			
		Hist. struc.	4% FTR limit	Price stabilization	Hist. struc.	4% FTR limit	1958-62 FTR limit	Price Stabilization
CS2j (cattle slaughter)	bil. lb.	12.7	12.9	13.2	15.4	16.3	16.6	17.1
CS3j (hog slaughter)	" "	9.2	9.3	9.3	10.9	10.9	10.9	12.3
SF3j (sows farrowing)	mil. hd.	6.4	6.4	6.5	6.4	6.5	6.4	8.0
FTR2j (beef imports minus exports)	bil. lb.	0.4	0.2	-0.1	1.0	0.4	0.5	0.05
FTR3j (pork imports minus exports)	" "	0.03	---	-0.06	0.1	---	---	-0.8
PWB2j (wholesale beef price)	cents	42.1	43.0	40.6	47.2	48.3	48.2	43.2
PWB3j (wholesale pork price)	"	41.5	41.5	42.9	43.2	43.2	43.3	45.8
P2jL (steer price)	"	25.4	25.8	25.9	28.1	28.9	28.9	28.4
P3jL (hog price)	"	16.6	16.6	17.5	16.2	16.1	16.2	17.6
P2jFC (feeder-calf price)	"	26.5	27.5	27.0	30.4	31.5	31.6	31.4
QPH2j (per-capita beef consumption)	lb.	42.0	41.5	41.5	46.9	46.1	45.9	47.8
QPH3j (per-capita pork consumption)	"	30.0	30.0	30.0	30.2	30.3	30.3	30.0

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4-percent limitation reduced net foreign trade in beef from a total of 7.6 billion pounds to 4.4 billion pounds—a 42-percent decrease. During the 1964 to 1975 period, net foreign trade in beef under the 4-percent limit totals only 8.4 billion pounds—60 percent less than the 21.1-billion-pound net import for the historical structure. The 1958 to 1962 average import level of just under 1 million pounds annually allows 10.7 billion pounds of net beef imports—50 percent of that obtained under no trade restrictions.

Estimated commercial cattle slaughter during the historical period is only slightly higher for the 4-percent limitation, but is 5 percent above the historical structure in the projection period. Commercial cattle slaughter for the absolute limit assumption is 7 percent above the base projections in the 1964 to 1975 period. The foreign trade limit on beef imports did not have any appreciable effect on the total commercial slaughter of hogs.

Per-capita beef consumption in the 9-year historical period (1955-64)—given the 4-percent foreign trade restriction—averages 0.5 pound less than the average per-capita consumption under the basic structure simulation. In the projection period, per-capita beef consumption under the variable trade limitation averages 0.8 pound less than that of the historical structure. Under the absolute net import limit, per-capita consumption during the projection period averages 1 pound less than that under the existing structure. The range in per-capita consumption is also 1 to 1½ pounds higher for the foreign trade controls. Average per-capita pork consumption is essentially the same, with or without beef import controls, but the range in per-capita pork consumption increases slightly in the case of the absolute-control assumption.

Wholesale beef prices average 90 cents per hundredweight higher in 1955-64, given the 4-percent control assumption, but average pork prices are the same under either assumption. However, the variable limit on beef imports, operative only in the last two-thirds of the 1955-64 period, increases the range in wholesale beef prices from 10.9 cents to 14.4 cents and the range in wholesale pork prices from 15.4 cents to 17.6 cents.

Wholesale beef price in the projection period averages about 1 cent per pound higher for either form of control, with a 2-cent wider range existing only in the case of the absolute limit. As in the historical period, pork prices are more variable under the beef import controls, but the means are the same.

Live prices follow wholesale price patterns. Feeder-calf prices average 1 cent per pound more in all import-control simulations and also exhibit a slightly wider range.

The number of sows farrowing in either the historical or projection period is essentially the same

with or without controls, but the range is up to 300,000 head greater for the control assumption.

At the end of the historical period, Jan. 1 inventories of beef cows are estimated to be 1.6 million head higher in 1964 under the trade-control structure, while steer inventories are 0.9 million head higher. In the 11-year projection period, beef-cow inventories increase 3 million head under variable controls and 1.9 million head under absolute controls, while steer numbers increase 2.1 and 1.2 million head, respectively, under variable and absolute limitations.

In general, either the variable or absolute limit on net foreign trade in beef increases commercial cattle slaughter, lowers per-capita consumption and raises price levels. However, the variability of most of the series is increased by the trade controls.

The restriction of net foreign trade in beef is simulated over the 1964 to 1975 period at 4, 7 and 10 percent of current domestic beef production. These restrictions are operative throughout the period with the exception of the 10-percent restriction which becomes operative in 1966. The mean values of selected variables over the 22 semiannual periods of the projection are shown in table 7.

According to the experimental results, commercial cattle slaughter increases as net imports are restricted; however, the restriction in net beef imports does not affect the average level of commercial hog slaughter. The increase in commercial cattle slaughter is approximately equal to the reduction in beef imports when comparing the experimental results in the case of two higher levels of restrictions; the average prices for these two assumptions are about the same. However, the 4-percent limitation results in an increase in domestic beef production that is less than the reduction in imports. Thus, per-capita consumption decreases and prices increase as the percentage level of the import quota is reduced.

Price stabilization

Control of the meat supply available for consumption (which involves the corollary assumption of guaranteed domestic prices) would turn the United States into a substantial meat exporter,

Table 7. Summary of estimated average levels of selected semiannual variables under different net import levels, United States, 1964-75.

Variable	Unit	Net foreign trade in beef restricted to:		
		4% BP2i	7% BP2i	10% BP2i
CS2j (cattle slaughter)	mil. lb.	16.3	16.0	15.4
CS3j (hog slaughter)	"	10.9	10.9	10.9
FT2j (beef imports minus exports)	"	0.4	0.7	0.9
H23 (other cows, Jan. 1, 1975)	1,000 hd.	47.8	47.5	44.1
QPH2j (per-capita beef consumption)	lb.	46.1	46.8	46.7
QPH3j (per-capita pork consumption	"	30.3	30.2	30.2
PR2j (retail beef price)	cents	71.7	70.7	70.9
RM2j (beef retailing margin)	"	23.4	23.3	23.4
PWB2j (wholesale beef price)	"	48.3	47.4	47.5
P2jL (steer price)	"	28.9	28.3	28.4
P2jFC (feeder-calf price)	"	31.5	31.3	30.7
PR3j (retail pork price)	"	64.1	64.1	64.1
RM3j (pork retailing margin)	"	20.9	20.9	20.9
PWB3j (wholesale pork price)	"	43.2	43.2	43.2
P2jL (hog price)	"	16.1	16.1	16.1

especially of pork. During the 9-year period, 1955-64, for example, net exports would have totaled 2.1 billion pounds of beef and 1.2 billion pounds of pork, instead of 7.6 billion pounds of net beef imports and 0.5 billion pound of net pork imports. In the next 11 years, the experimental results show a total net import of beef of only 1.2 billion pounds compared with net imports of 21.1 billion pounds under the present market structure. Moreover, net pork imports of a modest 2.4 billion pounds over the next 11 years change, in the experimental results, to net pork exports of 16.9 billion pounds—slightly more than 10 percent of the projected commercial hog slaughter.

Commercial cattle slaughter increases 9 billion pounds during the historical period in the price-stabilization experiment, while there is no change in total commercial hog slaughter (figs. 22 and 23). However, in the 11 years of the projection period, commercial cattle slaughter, given the supply available for consumption control, totals 11 percent more than that under the base structure, while commercial hog slaughter increases 13 percent over the projected base structure.

Per-capita consumption of beef and pork averages about the same in the price-stabilization experiment as it did under the existing structure during the 1955-64 period; however, there is no cyclical variation under price stabilization, compared with a range of 8.7 pounds for beef and 4.7 pounds for pork under the existing structure. In the projection period, per-capita beef consumption under controls averages 1 pound above the projected base simulation. Per-capita pork consumption

is the same in both the base and control simulations—namely, 30 pounds for a 6-month period.

In the 9-year historical period, 1955-64, wholesale beef prices average 42.1 cents per pound, with a range of 10.9 cents. Given the supply for consumption control, the average beef price falls to 40.6 cents per pound, but the range in the 1955 to 1964 period is reduced to 5.4 cents. Wholesale pork prices under price stabilization during the historical period average slightly higher (42.9 cents versus 41.5 cents), but the price range is reduced from 15.4 cents to 6.1 cents per pound.

In the 11-year projection to 1975, the controlled wholesale beef price averages 48 cents per pound, 1 cent above the average price under the historical model. Price variation is reduced from 15.4 cents to 4 cents per pound. The mean of projected pork prices, given price stabilization, is 45.8 cents, with a variation of only 1.9 cents, compared with a mean pork price for the base structure of 43.2 cents per pound with a variation of 9.1 cents.

Live cattle and hog prices follow wholesale prices. In the projection period, the variation in Choice steer price is reduced from 9.9 cents to 2.3 cents per pound, while the variation in hog price is reduced from 4.8 to 2.1 cents per pound.

Feeder calf prices average 50 cents to $1 per hundredweight higher for the price-stabilization assumptions than for the historical structure. The feeder price is somewhat more variable than wholesale or slaughter price; nevertheless, the variation in feeder calf prices is cut from 19 cents per pound in the 1975 historical projection period to 8 cents per pound in the 1975 control projection.

Fig. 22. Estimated per-capita beef consumption, wholesale price of Choice grade beef-steer carcasses at Chicago and beef cows on hand Jan. 1, price-stabilization experiment, United States, 1955-75.
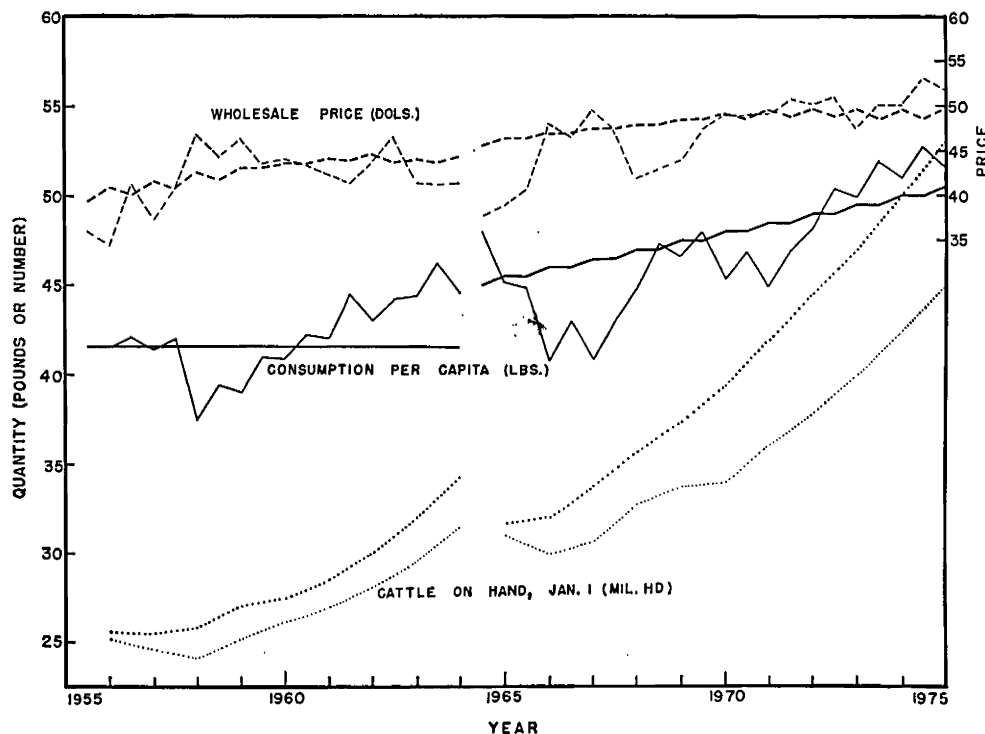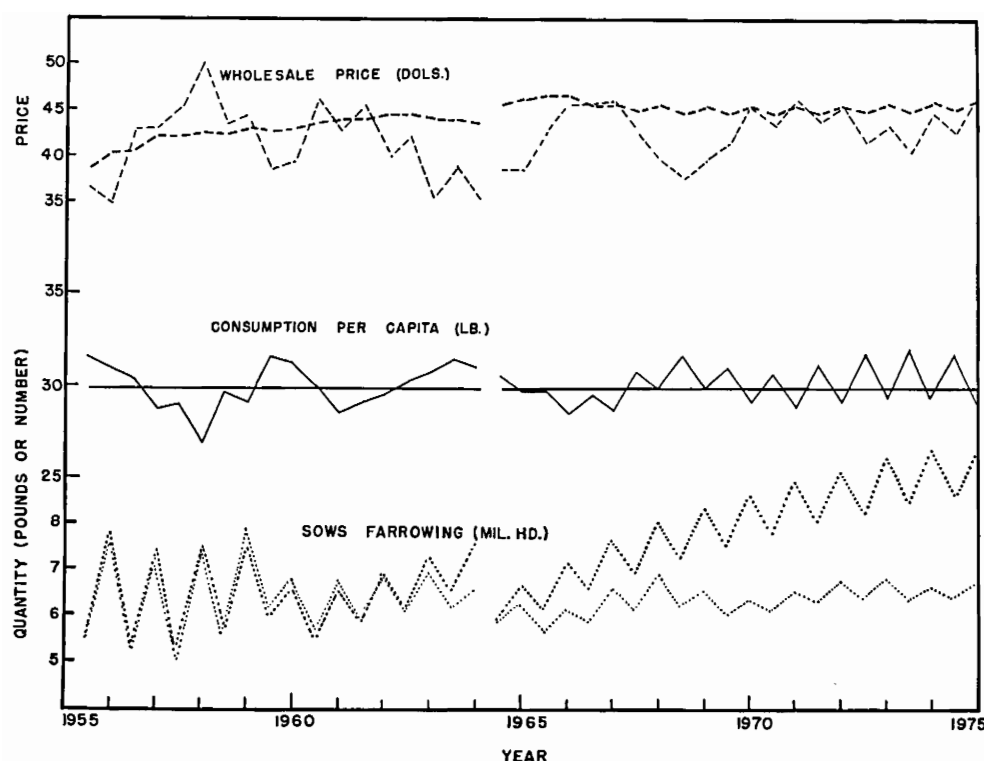
Fig. 23. Estimated per-capita pork consumption, equivalent wholesale price of pork cuts at Chicago and sows farrowing, price-stabilization experiment, United States, 1955-75.

The number of sows farrowing in 1964-75 increases 25 percent under the price-stabilization assumption. In the historical period, beef-cow and steer numbers on Jan. 1 increase 9 and 11 percent, respectively, over Jan. 1, 1964, historical structure levels. In addition, there is no cyclical downturn during the period. Similarly, beef-cow inventories rise to 53 million head in 1975—18 percent above the estimate for the historical structure. Steer inventories also increase to 20.5 million head in 1975—23 percent above the estimate for the base simulation.

EVALUATION OF MARKET EXPERIMENTS

The experimental results can be evaluated in light of the policy goals of price and output stabilization, reduction of marketing margins, and minimization of trade restrictions. The goals of effective competition, economic returns to investment and consumer sovereignty also can be used to evaluate the experimental findings. In this section, therefore, the simulated performance of the livestock-meat economy is viewed in the context of the introductory remarks pertaining to the basic policy issues.

Marketing Margins

For the historical period, the market experiments yield essentially the same results with reference to pork output regardless of margin assumption. However, all alternative margin assumptions restrict beef output compared with output in the historical-base simulation. The reduction in beef output is the result of a sharp reduction in cattle in-

ventories during the downturn of the cycle early in the period. Cattle numbers do not regain the earlier loss in subsequent years.

The fixed-margin assumption results in a greater range in commercial hog slaughter, per-capita pork consumption and sows farrowing because of a slight increase in the amplitude of the output cycle for the hog sector. The greater restriction of commercial cattle slaughter, consumption and year-end inventories under the fixed margin during the historical period does not necessarily mean a reduction in the amplitude of the output cycle, since the range of these variables over the period is about the same.

The price series in the margin experiments show an increase in the cyclical amplitude from the variable to the semivariable to the fixed margins in both the historical and the projection periods. The range in wholesale prices under the fixed margin is 4 to 5 cents above that of the variable margin during the historical period and twice that of the variable margin in the projection period. The variation in live prices and feeder prices is identical. In the simulation of the past 9 years, 1955 to 1964, the fixed- margin strategy suggests the possibility that the cattle cycle may have turned down in late 1960 and 1961. This possibility is suggested by the two alternative margin experiments as well as by the simulation of the historical structure. The simulation of the closed system supports the hypothesis of a 4- or 5-year cattle cycle.

With reference to the market policy objective of reducing live animal price flucations, the experimental results show that, in the case of the histor-

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ical period, Choice steer prices under the alternative margin asumptions fell below $24 as follows: variable-margin, five times; semivariable margin, four times; and fixed margin, five times. A Choice steer price in excess of $30 was obtained once with the fixed-margin assumption.

With reference to hog prices, the price level under the historical structure during 1955-64 fell below $13 twice and exceeded $19 three times. During the historical period, the price level exceeded $19 twice with variable margins and five times with semivariable and fixed margins. Hog prices for the historical period fell below $13 three times with fixed margins and once with semivariable margins but did not fall below this point with variable margins.

In the projections to 1975, steer prices fell below $24 five times and exceeded $30 four times with the fixed-margin assumption. The abnormally low prices were not obtained with the variable and semivariable margin assumptions during the projection period; however, steer prices exceeded $30 one and three times, respectively. Hog prices also exceeded the $13 to $19 range in the 1975 projections most frequently with the fixed-margin assumption. Hog price exceeded $19 four times and fell below $13 six times with the fixed-margin assumption. With the variable margins, prices were between the limiting values, while they dropped below $13 twice and exceeded $19 once with semivariable margins.

The fixed margins increase cyclical amplitude, especially price amplitude. Insofar as prices are flexible, the increased output variability under fixed margins intensifies the price cycle. A fixed margin also tends to restrict output. The semivariable margin tends to perform similarly; however, if the fixed portion is small, the variable portion results in a behavior response more closely approximating that of the completely variable margin; this is the case in the projection series in which the fixed component is not allowed to increase with the price level.

The average wholesale-to-retail margin is lower under the variable-margin strategy than under the semivariable and fixed-margin strategies, unless the semivariable margin has a relatively small fixed component. The producer, therefore, is viewed as preferring a variable-margin strategy if he wishes to realize a greater share of the consumer dollar. On the other hand, the consumer is interested in obtaining a given per-capita consumption for as low a price as possible. When retail prices (wholesale price plus the retail margin) are adjusted to a common per-capita consumption, this norm may be applied to the prices generated by the simulation of alternative margin strategies.

The fixed margin yields a lower average retail price for a given per-capita consumption, while the variable margin yields the highest average retail price for any given consumption level. This is particularly true in the case of beef prices in the projection period. The lower retail price under the fixed margin might be expected in this case, since prices are rising rapidly during the projection period.

Net foreign trade is slightly greater with the semivariable than with the variable-margin assumption and lower with fixed margins; however, the difference is not appreciable. Therefore, marketing margins appear to have little effect on net foreign trade.

With reference to the notion of consumer sovereignty, knowledge of quality and protection from fraud could be enhanced within the context of each of the three alternative margin assumptions. In any case, the reflection of consumer desires to the producer may be assessed as follows: In the 1955-64 period, the intersection of the derived demand curves under the fixed and variable margin assumptions occurred at a wholesale price of 43 cents (60-cent retail price) for both beef and pork. For the 1964-75 period, the equilibrium wholesale price is 58 cents per pound (80-cent retail price).

The computer experiments, given a variable margin, are preferred to the results based on fixed margins in terms of cyclical stability, lower margins, greater output and price flexibility. Average wholesale prices and average live prices are about the same for both the historical and the projection periods regardless of the form of the margin. The fixed margin provides the consumer with a given amount of meat at a lower price in almost all instances during the projection period, but simply because of the level of the fixed margin. During a period of declining retail prices, the fixed-margin assumption would penalize the consumer because of higher retail prices.

Foreign Trade Limitation

The 40- to 60-percent curtailment of net foreign trade in beef under either the assumption of variable or absolute limits is contrary to the notion of minimizing trade restrictions. The need for governmental supervision of beef imports and exports also would add to the participation of government in private industry, thus violating the notion of minimum public regulation and cost.

Domestic beef production increases under both forms of trade limitation; the simulation runs for the period to 1975 suggest that increases might be slightly greater under the absolute limit. Per-capita consumption of beef declines as much as a pound in spite of increased domestic beef production (because of lower import levels). Pork consumption is unaffected by the limitation of beef imports.

Average wholesale and retail beef prices are 1 to 2 cents per pound higher under trade limitation for the projection period; moreover, the amplitude of the beef price cycle is increased substantially, and

some of this increased amplitude is carried over into pork prices, even though average pork price remains about the same as in the projection of the historical structure. The 1958-62 average import limitation in the projection period is not as restrictive as the variable limitation, but a greater cyclical amplitude is evident in the absolute-limit than in the variable-limit model. In the projections to 1975, steer prices fall below $24 three times under the 4-percent limit, but not once under the absolute limit.

The wholesale-to-retail margin in the trade-control model is the same as in the historical base model by assumption. However, the retail price for a given per-capita consumption is not fixed. Nonetheless, there is essentially no difference in consumption between either of the quota models and the base simulation. Average wholesale prices are $1 higher over both simulation periods, and live-animal prices are 50 cents to $1 higher. Feeder-calf prices average $1 higher under trade limitations.

In summary, trade limitations increase cyclical amplitude, raise producer and consumer prices, and reduce domestic consumption. Returns to domestic investments in the livestock-meat economy could be improved, if other costs are held in check, but at the expense of the consumer.

Price Stabilization

Control of the meat supply available for domestic consumption, with a guaranteed price for beef and pork, virtually eliminates the price and output cycles in cattle and hogs, according to the experimental results. Some cyclical variation persists in the feeder-cattle market. The price both of dressed beef and pork and of live animals averages slightly above that of the historical base simulation in both the historical and projection periods despite substantial exports at world prices. In the 1955-64 simulations, wholesale beef prices average $1 more than that of the historical structure, while pork prices averaged $2 higher than that of the historical structure. Slaughter-animal prices and feeder-calf prices are about 50 cents to $1 above those predicted by the historical simulation. January 1 inventories of cattle and hogs increase sharply under the guaranteed domestic price assumption.

Use of the fixed wholesale-to-retail margin assumption and a fixed wholesale price results in simulation runs in which the producer's and processor's share of the consumer dollar varies with the amount of exports needed to maintain consumption at the specified levels. During the historical period, given per-capita consumption, the retail beef price averages 1 cent per pound higher, while the retail pork price averages 2 cents per pound higher.

The price-stabilization program leads to a net exporter position for the United States in pork during both the historical and projection periods. Imports of beef are necessary to maintain consumption during the projection period, but total beef imports are only a fraction of the predicted levels, given the historical structure.

USES AND LIMITATIONS OF SIMULATION TECHNIQUES

Simulation is a technique that allows limited reproduction of specified characteristics of a segment of some particular environment, in this case a portion of the characteristics and environment of the livestock-meat economy. The limitations are severe for the obvious reasons of cost and manageability. As a result, the conclusions must be partial and limited to the incomplete set of circumstances studied.

These important limitations not withstanding, the computer experiments presented here show in considerable detail the extent to which changes in specific economic circumstances affect prices and output. These experiments isolate and, in a limited sense, measure the impacts of changes that may arise from changes in weather, changes in technology, or changes in governmental or firm policy on the basic economic structure of the industry.

Except for the addition of bigger and better computers, simulation experiments are not new. But the addition of computers to this technique is a development of vast significance. In simplest terms, it allows integration of the results of a fantastically greater complex of economic forces than could be handled by other means. It adds a depth of reality and meaning to the conclusions derived from models that could not be approached previously. Although simulation models are still models, and therefore abstractions from reality, computers have allowed the addition of many elements of reality to the models and, therefore, to the evidence generated and the conclusions warranted.

A unique feature of the reported computer experiments is their strategic contribution to research organization. The tests and validation of these models provide important information inputs that will be helpful in the design of analytical tools and techniques. They demonstrate the pressing need for more complete and more refined data; and they enforce with impartial discipline the care with which statements of the major structural features of the economy are specified, as well as the coefficients and variables employed and the programming procedures used. As a result, these models are analytical through the tests of their design as well as in the evidence they generate regarding the impacts of changes in economic conditions.

The data problems encountered in this study are persistent and serious, but not overwhelming. They limit the reality of the evidence and, thus, the direct

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application of the conclusions. Spreads between retail and live prices, for example, must be estimated as functions of endogenous variables before the complete impacts of supply changes can be evaluated. The need for these and other data and functional relationships are presented here in sufficient detail so that specific data needs can be identified with respect to their expected uses in analyses and policy evaluation.

The market experiments illustrate also the interdependence of means in the light of particular ends and of ends in the light of available means to attain them. In brief, the use of the model entails more than simply recognizing the multiplicity of goals; it offers a series of results that require for their interpretation continuous interaction between the technician and the decision-maker.

It is true that simulation models involve large numbers of assumptions. But a simple economic model also involves a large number of assumptions, usually hidden rather than explicitly stated. Because reality is extremely complex, only by oversimplification can this basic problem be overcome. The assumptions of simulation models are neither unique to this class of models, nor a more serious weakness.

Many of the assumptions were stated explicitly as the model was developed and program modifications were introduced. In addition, several implicit assumptions are involved in the model and should be considered, either in developing similar models or in interpreting results of the alternative market simulations. First, the cost of feed inputs, as represented by the price of corn, is considered as an exogenous variable. The output-increasing effects of the alternative market conditions simulated might have resulted in an alteration in government price-support operations.

Treatment of the wholesale-to-retail price spread as an exogenous influence was justifiable in reproducing the historical period as well as in simulating fixed-margin policies. However, endogenous forces might influence the wholesale-to-retail spread under the trade-limitation and price-stabilizing policies.

The alternative market conditions were assumed to have no effect on the coefficients of phenomena, such as consumer taste, that are represented by trend terms. In practice, changing conditions might change either the value of the trend coefficient or its sign.

In the projection series, weather conditions, as represented by range conditions, were projected at their historical mean value. Income was also projected as an extrapolation of the historic trend. Lack of weather and business cycles allows industry expansion at a more rapid rate than under "real world" conditions. However, the elements of uncertainty stemming from these exogenous influences are implied in the estimated coefficients.

The alternative forms of market organization could also affect two elements of the endogenous structure in an implicit fashion. During the simulation over the historical period, the ratio of federally inspected cow slaughter to nonfederally inspected cow slaughter was assumed to be constant. Changing conditions could change the demand for cow-beef in interstate commerce by an amount large enough to affect this ratio.

Finally, treatment of the foreign-trade relationship on a net basis (imports minus exports) only estimates the net availability for consumption. It does not allow for increased farm production stemming from a higher level of exports. Such an increase is not likely.

Because of the lack of adequate data involving foreign trade in meat, the results of the price-stabilization experiment must be interpreted in full view of the assumption that export prices, f.o.b. the United States, would hold in spite of the substantial increase in domestic exports.

With reference to the agricultural production implication, the price changes are worked out in substantial detail; their effects on inventories and, ultimately, on farm production are explored with reference to different levels in the production and marketing sequence. Again, certain data inadequacies are revealed that suggest a need for future data improvement.

Finally, the model succeeds when it reproduces the historical data with minimum error. At this point, it approaches an acceptable degree of precision of generating the selected time series. When the best available estimates of the current and future economic relationships are used, projections of future output and prices are generated. When these relationships are altered to simulate specific changes, the time paths of the relevant variables generate evidence of the impact of the assumed changes.

Because the economic objectives have not been completely specified, the simulated economy is not optimal in every respect. It is quite possible, however, that with reference to a large-scale industrial activity or an entire area economy, the usual performance goals will not be achieved under the most likely market circumstances of an unregulated market. In such a situation, the market experiments based on a simulated economy would be more realistic than those obtained with an optimizing model. However, by adding restraints to optimizing models and disaggregating simulation models, essentially the same results will be generated.

Finally, the model does not deal with the detailed processes of market adjustment and human behavior. Indeed, it lays aside an intensive examination of behavioral responses. In so doing, however, it enhances the role of the generalist in decision making; it welds the policy maker and the technician together in a complementary fashion as they face the critical task of interpreting the policy implications of the computer experiments.

Validation of the Model

Indexes of dispersion and turning-point errors were calculated for all series except beef and pork production, since these variables are almost identical to commercial slaughter in both direction of movement and degree of variation. These two statistics are presented in table A-1.

For many of the production and inventory variables, a divergence of 1 or 2 percent would represent a substantial deviation in absolute value. Also, the degree of accuracy is more important for the major components of the consumption identity than for the minor components. A high degree of accuracy in estimating commercial cattle and hog slaughter, beef and pork production, and net foreign trade in beef is important in the estimate of per-capita consumption, since these variables essentially determine consumption. Although ending stocks and net foreign trade in pork enter into the computation of the consumption identity, they make up a relatively small percentage of per-capita consumption.

The objective of predicting per-capita consumption within 1 pound of the reported value was discussed earlier. Inspection of the per-capita consumption series in table 2 shows that a prediction with error of more than 1 pound occurred only once for per-capita beef consumption and once for per-capita pork consumption.

Table A-1. Indexes of dispersion and turning-point errors for semi-annual estimates using computer model of livestock-meat economy, 1955-64.

Variable	Index of dispersion	Turning-point error
CS2j (cattle slaughter)	0.0086	2/15
CS3j (hog slaughter)	0.0095	7/10
F1C2j (cow slaughter)	0.0545	1/16
FTR2j (beef imports minus exports)	0.0956	3/14
FTR3j (pork imports minus exports)	0.3499	8/9
ES2j (beef ending stocks)	0.1143	0/17
ES3j (pork ending stocks)	0.0414	3/14
AWFSj (av. wt. steers)	0.0054	3/14
QPH2j (per-capita beef consumption)	0.0063	2/15
QPH3j (per-capita pork consumption)	0.0094	1/16
(wholesale beef price)	0.0080	0/17
(wholesale pork value)	0.0284	1/16
(steer price)	0.0088	0/17
(hog price)	0.0430	3/14
(feeder-calf price)	0.0266	4/13
(cow slaughter)	0.0436	4/5
H21 (other calves)	0.0054	1/8
H22 (other heifers)	0.0152	2/7
H23 (other cows)	0.0044	0/9
H24 (steers and bulls)	0.0056	0/9
H26 (cattle on feed)	0.0177	1/8
H32 (sows and gilts)	0.0085	1/8
SF3j (sows farrowing)	0.0101	2/15

The performance of the model in reproducing the historical period was deemed satisfactory considering the degree of accuracy needed for each variable. The seven turning-point errors in the predictions of commercial hog slaughter would be unacceptable if long-run forecasting were the prime objective. The experimental results for commercial hog slaughter were accepted, however, since the deviation from the reported values was low despite the error in direction of change. If the computer model had been programmed to react to forecast values, correct prediction of the direction of change would be crucial. In this model, where the program does not include a reaction to forecast values, the turning-point error is not serious.

Most of the dispersion error in wholesale pork and live hog price is associated with overestimates of production the last 2 years (because of the trend term in the fall sows-farrowing equation). Although the leveling off of the trend in sows farrowing in the fall during the early 1960's is difficult to verify statistically, it is recognized that, on logical grounds, the continued operation of the trend term in the fall sows-farrowing equation would soon yield estimates of fall farrowings in excess of spring farrowings. Although the trend phenomenon may soon stabilize farrowing throughout the year, the possibility of fall farrowings exceeding spring farrowings is not likely.

Wholesale beef price and steer price have low dispersion indexes. Feeder prices are more variable than steer prices. In all cases, the turning-point error of the price variables is low.

Although the index of dispersion of net foreign trade in pork and ending stocks of beef are 0.3499 and 0.1143, respectively, this amount of error in the estimates of these variables is allowable, since they are not major components of the consumption identity. Most of the error in the estimates of net foreign trade in pork occurred in the 1958 and 1959 estimates during the transition to a higher level of imports.

The error in federally inspected cow slaughter on a liveweight basis is not considered excessive. The use of cow slaughter as a decision rule in the wholesale-beef price equation makes the directional change as important as the moderate dispersion error.

The most serious error in the system occurs in the case of federally inspected beef-cow slaughter on an annual basis. Accurate estimation of this variable is a crucial part of the estimation of Jan. 1 beef-cow numbers. However, the error in the simulation of reported beef-cow numbers is within acceptable limits.

Tests of Variance

Although validation of the computer model might be accomplished merely by graphing the predicted and actual values, several quantitative methods are available. Orcutt (42, p. 898) suggests that a

simple regression of the form,

$$y = a + bx, \quad \text{(Eq. 4.1)}$$

be fitted to the predicted and actual data. A perfect simulation of the historical period would yield an "a" of 0 and a "b" of 1. The estimated value of these parameters could then be tested with Students' "t" distribution to see if the estimates were significantly different from 0 to 1.

Theil (50, p. 32 and p. 170) suggests a combination of two tests for forecast values to be used in conjunction with each other. First, a turning-point error may be evaluated where the following ratio is formed:

$$TPE = (f_{12} + f_{21}) \div (f_{11} + f_{22}) \quad \text{(Eq. 4.2)}$$

where "f" refers to the direction that the individual observations take from the previous period. The first subscript refers to the predicted value, while the second subscript refers to the actual value. A subscript of 1 denotes an increase from the previous period; a subscript of 2 denotes a decrease from the previous period.

Theil also suggests an index of dispersion, U, to measure the degree of deviation of predicted from actual values. It is calculated as,

$$U = [1/n \ \Sigma \ (P\text{-}A)^2]^{\frac{1}{2}} \div (1/n \ \Sigma \ p^2)^{\frac{1}{2}} + (1/n \ \Sigma \ A^2)^{.\frac{1}{2}}$$
$$\text{(Eq. 4.3)}$$

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