A POLICY ANALYSIS OF THE UNITED STATES
VEGETABLE OILSEEDS, OILS, AND OIL PRODUCTS INDUSTRY
WITH SPECIAL EMPHASIS ON OPTIMAL CONTROL

by

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1. INTRODUCTION

This section provides a brief introduction to the problems, objectives, and methods considered in this study. Section 1.1 discusses several of the major problems in the construction of econometric models of commodity markets and relates these problems to the effort undertaken in this study. Section 1.2 explicitly states the objectives of the study and discusses the relevance of other similar empirical studies. Section 1.3 describes the methodological approach utilized in attempts to satisfy the study objectives and elaborates on the organization of the dissertation.

1.1. Some Unresolved Problems in the Construction of Econometric Models of Agricultural Markets

In recent years there has been a concentrated effort in the development of both large-scale agricultural and sectoral commodity econometric models. The principal large-scale agricultural models are the Wharton, the Data Resources, and the Chase econometric models. In addition, many smaller more specialized econometric models of commodity markets have been constructed in recent years. A review of a number of these models is presented in Labys [33]. One basic distinction between large-scale econometric models of agriculture and sectoral commodity models is that the former typically are horizontally linked over many basic raw product markets, while the latter usually consider only a few product markets and are vertically linked from consumer back to derived demands for raw products. In addition, sectoral commodity models typically provide more detailed specifications of the markets analyzed than the large-scale agricultural models. Another important difference between large-scale econometric models of agriculture and sectoral commodity models is that the former generally treat agriculture as part of a large simultaneous system while simultaneity in sectoral commodity models is limited to the included markets.

The construction and use of econometric models in agriculture has been openly criticized in the past. Tweeten [67, p. 181] notes that King has emphasized that "econometric analysis has failed to contribute fully to forecasting and decision-making in agriculture for a lack of a comprehensive, sustained effort." Regarding the same subject, Tweeten [67, p. 181] has gone so far as to suggest the establishment of a national institute "to perform the development function, building a comprehensive econometric model of the agricultural sector and transforming basic and applied research into a form useful to decision-makers." Other criticism has come from Cromerty and Myers [14] who have chastized model builders for being more concerned with the use of sophisticated econometric techniques--the derivation of unbiased estimators, for example--than they are with the correlation between their models and the real world. This situation occurs frequently when econometricians have only a limited knowledge of the complexities and workings of the markets they are modeling. Cromerty and Myers also have suggested that the time period of observation in some models is so long that most of the effects of demand and supply shifts are not incorporated. Decision-makers are interested in short-run analysis.

In general, the development of econometric models in agriculture has lagged behind the development of macroeconometric models. However, there are several important reasons for this. The first, and perhaps most important reason is that it has been only in recent years that the price support system has been abandoned and agricultural prices have been allowed to move unconstrained in a market economy. The relatively free movement of prices and quantities is generally a principal assumption underlying the construction of most macroeconometric models and is in most cases a necessary condition for the existence of the model. Second, agricultural economists are normally trained to use many different analytical techniques--mathematical programming and simulation, for example. This means that a total reliance on econometrics as a basic empirical tool is not necessary. However, the macroeconomist who performs empirical analyses typically utilizes econometrics as his basic empirical technique. For this reason, agricultural economists have not progressed as rapidly in this area as macro-analysts. Third, much of the technology necessary for performing large-scale econometric studies has become available only in the last decade. There is necessarily a time lag between the development and implementation of new methods and technology--this lag has been greater in agricultural economics.

The basic problem encountered in attempts to construct large-scale agricultural models is that large amounts of resources are required for the endeavor. The management of the necessary data base, the programming effort, the specification of the model and subsequent analytical applications for large-scale models are significant problems which require numerous specialists for practical solution. Also, large amounts of capital are necessary to construct and maintain large-scale econometric models. The ultimate question which emerges then is, given the existence of only a few large-scale commercial econometric models with sufficient resources for maintenance, to what degree will these models be used for domestic policy analysis? Unless there is direct incentive to commercial firms in the form of beneficial public relations or cash transfer, there is likely to be little or no reason to perform policy analysis (except in so far as policy changes may effect their clients). A significant role is then assigned to the builders of sectoral commodity models--they are to construct market models and perform policy analyses which would not otherwise be undertaken.

1.2. Objectives of the Study and a Brief Review of Related Studies

Many empirical models of commodity markets use separate functions to represent production flows and flows from inventory-stocks to markets. The theoretical foundations for this utilization are often obscure, however, and the implication is that these functions are purely empiric. A theoretical basis for production-flow and inventory-stock functions does exist in the literature, although the arguments presented in the appropriate sources are not always clearly linked. The first objective of this study is to present, and develop where necessary, a discrete dynamic market equilibrium model capable of explaining the dual role of supply flows from production and inventory-stocks. Given the appropriate theoretical foundation, the second objective of the study is to specify a sectoral commodity model of the United States vegetable oilseeds, oils, and oil products industry.

After estimation of the sectoral model, and testing to assure its validity, the third objective of this study is then to utilize the vegetable oilseeds, oils, and oil products model to analyze policy alternatives through dynamic simulations. The principal focus of the simulations is on the potential of implementing new policies deemed politically feasible, although the impacts of historical policies on the industry are also considered. The final objective of the study is to utilize the industry model to illustrate the potential of optimal control theory for price stabilization. To satisfy this objective, an agricultural control agency is proposed with responsibility for controlling buffer stocks of commodities.

A number of studies on markets in the domestic vegetable oilseeds, oils, and oil products industry have been conducted in the past. Anderson [1] analyzed the derived demands for soybean oil used in margarine and shortening. Vandenborre [75] developed a simultaneous equation model of the soybean oil and meal markets. Houck, Ryan, and Subotnik [28] developed a simultaneous equation model of the soybean oil, soybean meal, and soybean markets, and analyzed the spatial aspects of the supply of soybeans. Matthews, Womack, and Hoffman [44], and Golden [25], extended the work of Houck, Ryan, and Subotnik by re-estimation of previously defined relations.

The model constructed in this study is a fundamental departure from previous work in three respects. First, the model is a monthly model--all previous work in this area has been performed with quarterly or annual models. The use of a monthly model allows short-run policy analysis to be performed. Second, the model developed in this study explicitly considers final product demands in its specification--no previous studies of the vegetable oilseeds, oils, and oil products industry have done this. The inclusion of final product markets in the model allows the effect of changes in raw product prices on the consumer to be evaluated. And third, the model developed in this study considers all the major oilseeds, oils, and oil products markets as components in its formulation. Again, no previous study has attempted to do this. The inclusion of all major substitute markets allows for a more complete evaluation of the workings of the system.

Policy analyses in previous studies of markets in the domestic vegetable oilseeds, oils, and oil products industry have been extremely limited in scope--the major concentration has been on structural estimation and prediction. The most complete policy analysis of the industry has been performed by Houck, Ryan, and Subotnik. In their study, yearly data were used to estimate a simultaneous equation system. Impact, interim, and total multipliers were generated to evaluate the effects of changes in policy variables. This analytical technique is somewhat limited, however, since multiplier analysis presumes that only one exogenous variable is changed at a time. A more useful technique for policy analysis is dynamic simulation. With simulation, changes in one or more exogenous variables are made for a specified time period, and the effects on the system are determined by comparing the distribution statistics of the time series generated by the model before and after the exogenous variables are changed. Policy simulation is the principal analytical technique utilized in this study, although impact, interim, and total system multipliers are reported.

The replacement of the price support system with the target price system has led to a great deal of discussion among agricultural economists concerning the relative merits of maintaining buffer stocks of commodities for price stabilization. In a simulation study of the feasibility of maintaining international buffer stocks for wheat, Reutlinger [53] found that, under certain arbitrary purchase and sales rules, the benefits of a buffer stock program can exceed the costs. In this study it is assumed that price stability is desirable, as indicated by the parameters of an assumed aggregate social welfare function, and that buffer commodity stocks are to be maintained to achieve domestic price stability. In addition, during years of high prices, embargoes on exports are allowed as instruments for maintaining price stability. The mechanism for determining the level of buffer stocks and the level at which embargoes are to be applied is optimal control theory.

The application of optimal control theory in agricultural economics has been limited. Early consideration of the usefulness of the technique was given by Tintner [65], Burt [7], Thompson [64], and Waugh [77]. However, the first empirical application of the technique was made by Rausser and Freebairn [51]. Other applications of control theory in agricultural economics have been made by Rausser and Howitt [52], and Kim, Goreux, and Kendrick [31]. A principal objective of this study is to suggest and illustrate the potential of utilizing optimal control theory for maintaining domestic price stability.

1.3. Methodology and Organization of the Dissertation

The methodological approaches utilized in this study are essentially traditional--no methodological innovations are introduced. The theoretical model is developed using differential calculus. The empirical model is estimated using ordinary least squares, and system estimation methods where appropriate. Policy analyses are performed using standard simulation techniques applied to econometric systems. In addition, optimal control applications are carried out following procedures previously outlined in the literature. Consequently, the major contribution of this study is based on the relevance of the empirical findings.

Section 2 presents a review of discrete dynamic theories of production and inventory maintenance. This review serves as a foundation for the derivation of the theoretical model presented in Section 3. A dynamic profit maximization model is developed in this section using classical optimization theory. Following optimization, solution vectors consisting of inventory-stock, production-flow, and derived demand functions result. Section 4 presents a theoretical specification of a model of the domestic vegetable oilseeds, oils, and oil products industry. A discussion of the problems of formulating and estimating an empirical model of the industry is then presented in Section 5. Section 6 relates the results of estimating the functions of the model and presents the final form of 4 sub-models which describe the domestic vegetable oilseeds, oils, and oil products industry. Section 7 presents the results of attempting to validate the econometric sub-models representing the industry, and gives the derived levels of impact, interim, and total dynamic multipliers for the simultaneous components of the industry sub-models.

The results of performing deterministic policy simulation experiments using the industry sub-models are discussed in Section 8. The simulations are carried out by altering the historic values of policy variables or other exogenous variables of interest, and then generating the values of endogenous variables which would result under the alternative scenario. Section 9 discusses the application of optimal control theory to agriculture, and the oilseeds, oils, and oil products industry, for maintaining price stability. Section 10 presents a summary and conclusion.

2. A REVIEW OF DISCRETE DYNAMIC THEORIES OF MARKET EQUILIBRIUM

Static economic theory still underlies a great deal of empirical work in most areas of economics. Even though there has been a great deal of progress in dynamic economics over the last twenty years--especially in attempts to qualify adjustment lags--dynamic economics remains largely a thing of the future. Economists are still a long way from specifying a set of empirically refutable propositions which can be said to truly represent a theory of dynamic economics (Nerlove, [48]).

Despite the fact that there is no adequate theory of dynamic economics, there has been a general recognition by economists of a fundamental market relationship that exists over time between the levels of inventory stocks and the production flow of goods to market. This is a dual relationship--inventory stocks and production flows are sources of market supply at any point in time. In the four sections which follow, a brief review is made of theories which have been offered to explain this dynamic dual relationship. Section 2.1 discusses an elementary case of discrete dynamic market equilibrium and introduces necessary concepts and notation. Section 2.2 discusses the theory of storage as developed by Working [79] and Brennan [6]. Section 2.3 reviews the production and inventory theory of operations research. Section 2.4 presents the social utility approach taken by Samuelson [56, 57] and Pliska [50].

2.1. The Classical Theory of Consumer and Firm Behavior

The central postulate of classical economic theory is that consumers maximize utility subject to income constraints and firms maximize profit subject to production function constraints. This concept, which was originally presented in a timeless dimension, has been often augmented by economists who perceived that their static theory often did not easily explain events in a dynamic world. Early attempts to produce a dynamic theory of consumer decision-making were made by Fisher [20] and Hicks [27]. Carlson's dynamic theory of producer decision-making [8] is perhaps the earliest attempt to describe the dynamic behavior of the firm.

The traditional static formulation of the consumer's decision problem requires the maximization of the individual utility function $u = \gamma(q)$ subject to the income constraint $y = p'q$. Optimization of the associated Lagrangian function leads to optimal solutions, when they exist, of the form

$$(2.1)\quad q_n^* = \delta\,(p,\ y) \qquad n = 1, \ldots, N$$

where q is an $N\mathrm{x}1$ vector of goods consumed by the individual with nth element q_n, p is an $N\mathrm{x}1$ vector of prices, y is a scalar representing income, $\gamma(\ldots)$ is a twice differentiable continuous function, and $\delta(\ldots)$ is a differentiable continuous function. The superscript * denotes the optimizing values of the control vector q and the prime mark represents a transpose. Relation (2.1) is the basic static demand function and states that the optimizing choices of the consumer depend on prices and income.

The static consumer decision problem is transformed into a discrete dynamic decision problem by redefining the consumer's utility function to be of the intertemporal form $u = \gamma(q_1, \ldots, q_T)$ where q_t represents an Nx1 vector of goods consumed by the individual in time period t. The sequence of intervals $t = 1, \ldots, T$ represents the life time or planning horizon of the consumer and defines the discrete domain of $\gamma(\ldots)$. Over $t = 1, \ldots, T$ the consumer has income $\Sigma y_t = \sum_{t=1}^{T} p_t{}'q_t$ where p_t is the Nx1 vector of prices associated with q_t in time period t. Maximizing the intertemporal utility function over the entire horizon subject to income over the horizon leads to solution vectors, when they exist, of the form

$$q^*_{nt} = \delta(p_1, \ldots, p_T; y_1, \ldots, y_T) \qquad \begin{matrix} n = 1, \ldots, N \\ t = 1, \ldots, T \end{matrix} \tag{2.2}$$

The demand for the nth good in period t is a function of all prices and incomes. The problem with this approach is that the optimization must be performed prior to the first period of the planning horizon. Since future prices and income are unknown to the consumer prior to their realization, relation (2.2), while enlightening, cannot adequately represent the actual decision calculus of the consumer.

A common method of overcoming the conceptual problems associated with the generation of (2.2) is to postulate the existence of a separable intertemporal utility function of the form $u = u[\gamma(q_1), \ldots, \gamma(q_T)]$. This approach has been used by George and King [23], and Bieri and de Janvry [4] as a foundation for using static demand functions in empirical studies. The maximization of the separable intertemporal utility function subject to income constraints leads to an optimizing control vector identical to that of the basic static case in (2.1). For this reason, with an intertemporal separable utility function, the dynamic problem degenerates into a series of T static maximization problems.

The traditional static formulation of the firm's decision problem requires the maximization of firm profit $h = p'q - v'x$ subject to the production function constraint $\phi(q, x) = 0$ where q is an Nx1 vector of goods produced by the firm, p is the Nx1 associated price vector, x is an Mx1 vector of input quantities, v is an Mx1 vector of input prices, h is a scalar representing profit, and $\phi(\ldots)$ is a twice differentiable continuous function. The output vector q and the input vector x are the firm decision or control variables, the levels of which are to be optimized. The price vectors p and v represent state variables which are treated as fixed parameters during optimization.

Maximization of h subject to $\phi(\ldots)$ by the Lagrangian multipliers method leads to general solutions, when they exist, of the form

(2.3) $\quad q_n^* = \sigma(p, v) \qquad n = 1, \ldots, N$

(2.4) $\quad x_m^* = \psi(p, v) \qquad m = 1, \ldots, M$

where $\sigma(\ldots)$ and $\psi(\ldots)$ are continuous differentiable functions. Relation (2.3) is the basic static supply function and (2.4) is the static derived demand function. Both quantity supplied and input quantity demanded by the firm are functions of all input and output prices.

The static firm decision problem is transformed into a discrete dynamic problem by redefining the firm's production function as the multiple period function $\phi(q_1, \ldots, q_T; x_1, \ldots, x_T) = 0$ where the vector subscripts denote the time period of vector initialization. Defining profit as $h = \sum_{t=1}^{T} p_t{}'q_t - \sum_{t=1}^{T} r_t{}'x_t$ and maximizing subject to the multiple period production function leads to solution vectors, when they exist, of the form

$$(2.5) \quad q^*_{nt} = \sigma(p_1, \ldots, p_T; v_1, \ldots, v_T) \qquad n = 1, \ldots, N$$

$$(2.6) \quad x^*_{mt} = \psi(p_1, \ldots, p_T; v_1, \ldots, v_T) \qquad m = 1, \ldots, M.$$

The supply of the nth good and the derived demand for the mth input in t are functions of all input and output prices.

The problem with the multiple period firm decision problem, like that of the multiple period consumer problem, is that the optimization must be performed prior to the realization of prices. The firm does not know what the levels of prices will be over $t = 1, \ldots, T$. For this reason the multiple period discrete dynamic framework described by (2.5) and (2.6) cannot offer an adequate explanation of the firm decision process.

2.2. The Theory of Storage

The theory of storage as developed by Working [79] and stated explicitly by Brennan [6] is in essence a discrete time generalization of classical static theory. Consumers are assumed to be utility maximizers and firms are profit maximizers, both within a competitive environment. The object of consumer demand and producer supply is not simply a quantity of goods, but quantities of stocks of goods. The basic postulate of the theory is that the demand for and the supply of stocks for storage provides an explanation for "the holding of all stocks, including those for which there is not an active futures market" (Brennan [6, p. 50]).

The demand for storage is developed in the theory of storage by rewriting the basic static demand function of the preceding section in the inverse function form

$$(2.7)\quad p_{nt} = \delta^{-1}(q_{nt} | p_{1t}, \ldots, p_{n-1,t}, p_{n+1,t}, \ldots, p_{Nt}; y_t).$$

The price of the nth good in t is a function of the demand for the nth good in t given other prices and income in t. The discrete dynamic identity

$$(2.8)\quad q_{nt} = s_{n,t-1} - s_{nt} + z_{nt}$$

is defined to exist over t = 1, ..., T for n = 1, ..., N, where s_{nt} is the quantity of the nth good in storage at the end of t, and z_{nt} is the quantity of the nth good produced in t. By defining the expected change in price of the nth good from t to t + 1 as $E(p_{n,t+1}) - p_{nt}$, and by substituting (2.8) in (2.7) it follows that

$$(2.9)\quad E(p_{n,t+1}) - p_{nt} = E[\delta^{-1}(s_{nt} - s_{n,t+1} + z_{nt} | \ldots)] - \delta^{-1}(s_{n,t-1} - s_{nt} + z_{nt} | \ldots).$$

From this relation it is clear that s_{nt} can be expressed as a function of $E(p_{n,t+1}) - p_{nt}$ or conversely. The relationship between expected price change and the level of stocks constitutes the demand for storage function.

The supply of storage function is derived directly from firm profit maximization. When storage is possible firms maximize the expected profit from storage. For the nth good in period t the expected profits from storage are

$$(2.10)\quad E(h_{nt}) = [E(p_{n,t+1}) - p_{nt}]\, s_{nt} - v_t{}'x_t$$

where v_t and x_t are vectors of input prices and quantities of dimension $M_1 \varepsilon M$ associated with storing the nth good from t to t + 1. Assuming the production storage function is of the simple form $s_{nt} = \phi(x_t)$, it follows that the necessary conditions for an expected profit maximum are

$$(2.11)\quad \frac{d\phi}{dx_{mt}}\,[E(p_{n,t+1}) - p_{nt}] = v_{mt} \qquad m = 1, \ldots, M_1.$$

The expected profit maximizing firm equates the value of the marginal product of storage and the input price for all inputs used in storage. Equivalently, this implies that the marginal cost of storage be equated with output price. Solutions to the expected profit maximization problem, when they exist, imply that the firm supply of storage function can be written as

$$(2.12)\quad s^*_{nt} = \iota[E(p_{n,t+1}), p_{nt}, v_t].$$

Firm supply of storage is a function of expected output price, current output price, and input prices. Equating (2.12) with the appropriate form of (2.9) leads, in general, to a unique market equilibrium.

2.3. Production and Inventory Theory

The central postulate of the theory of storage is that the inventory level for a stored commodity is an explicit decision variable for firms maximizing expected profit. However, the level of production is treated as a state variable by the theory of storage--production decisions are treated parametrically. Operations research production and inventory theory generally takes a converse approach--the level of production is treated as the decision variable while the level of storage is taken as a deterministic or stochastic state variable. The assumption of storage as a state variable is a common characteristic linking the different types of operations research models which have been developed to deal with production and inventory problems.

Another important characteristic which distinguishes operations research production and inventory theory from the theory of storage is the nature of the design goals of the theories. As Sengupta and Fox [59] have noted, the economist is interested in developing a deterministic theory of firm behavior and in the aggregative aspects of economic behavior. The economist wants to know what decision rules, if followed by individual firms, explain fluctuations in market production and stocks. The operations researcher, on the other hand, is more interested in specifying the optimal decision rules a firm should follow in order to satisfy varying objectives.

A general representation of the standard operations research treatment of the production and inventory problem can be made in terms of a probabilistic dynamic programming problem. Let $t = 1, \ldots, T$ represent the decision horizon of the firm with $t = 1$

representing the last stage of the dynamic programming problem and $t = T$ representing the first. The demand for firm output in t is represented by the random vector q_{kt} which occurs with discrete probability $P_{kt}(q_{kt})$ in t for the kth discrete interval. The firm decision vector is z_t, the quantity of N goods produced in t. Firm stocks at the beginning of period t are represented by s_t. The vector s_t is a stochastic state variable obtained from the identity

(2.12) $$s_{t-1} = s_t + z_t - E(q_t).$$

Firm stocks are presumed to be stochastic because once z_t^* is determined, given s_t and $E(q_t)$, s_{t-1} is determined. The probability of q_{kt} occurring corresponds with the probability of s_{kt-1} occuring.

All unsatisfied demand in t is assumed lost. For this reason the market clearing vector q_t possesses an independent distribution over $t = 1, \ldots, T$. Expected firm profit in t is defined as

(2.13) $$E(h_t) = \sum_{k=1}^{K} P_{kt}(q_{kt}) \cdot [p_t' \cdot \min\{q_{kt}, s_t + q_t\} - v_t'x_t]$$

which is to be maximized subject to the firm production constraint

(2.14) $$\phi(s_t, z_t, x_t) = 0.$$

By incorporating the production function constraint in the appropriate Lagrangian function the stage t objective function becomes

(2.15) $$L(z_t, x_t, \lambda_t) = \sum_{k=1}^{K} P_{kt}(q_{kt}) \cdot [p_t' \cdot \min\{q_{kt}, s_t + z_t\} - v_t'x_t + \lambda_t\phi(s_t, z_t, x_t)].$$

The components of the objective function for the next programming stage, $t - 1$, are weighted by the probabilities that q_{kt} was realized in t:

$$(2.16)\quad L(z_{t-1}, x_{t-1}, \lambda_{t-1}) = \sum_{k=1}^{K} P_{kt}(q_{kt}) \cdot [\sum_{k=1}^{K} P_{k,t-1}(q_{k,t-1}) \cdot (p_t' \cdot \min\{q_{k,t-1}, s_{t-1} + z_{t-1}\} - v'_{t-1}x_{t-1} + \lambda_{t-1}\phi[s_{t-1}, z_{t-1}, x_{t-1}]))].$$

By defining $f_t(s_t)$ as the value of the returns function in t, the overall objective function is described by the recursive relation

$$(2.17)\quad E[f_t(s_t)] = \max_{z_t} \{L(z_t, x_t, \lambda_t) + E[f_{t-1}(s_{t-1})]\} \quad t = 1, \ldots, T.$$

This sequential optimization of Lagrangian functions leads in the continuous case directly to a solution for the correspondent expected profit maximum. In terms of firm supply, the quantity supplied in any period is represented by (2.12). The inventory-stock function does not exist for this problem--inventory stock is presumed to be a stochastic state variable. A production-flow function in terms of z_t^* can be written in terms of the problem parameters in t. However, the result is not analogous to that obtained in Section 2.2. An unconstrained version of this problem is presented by Gottfried and Weisman [26].

There are three important differences between the theory of storage and the production-inventory theoretical approach of operations research. First, the theory of storage assumes the existence of competition. The firm is able to sell an unlimited quantity of product at the existing market price. This is not possible in the market environment specified in the operations research approach. The demand for the firm's product is given by the market. The firm can supply this amount--no more and no less. Hence the inventory and production theory of operations research is inconsistent with the classical economic theory of competition. Second, in the theory of storage, firm stocks are assumed subject to control by the firm. The firm decides the quantity to be stored from t to t + 1. In inventory and production theory firm stocks generally are assumed to be a stochastic residual left over after demand is satisfied. Third, the theory of storage does not consider production in its formulation--production is treated as a state variable. In inventory and production theory, quantity produced is a control variable of central interest.

2.4. Expected Net Social Product Maximization

Recently Pliska has attempted to combine stochastic production with the supply of storage theory to yield a model of commodity price formation. Pliska's approach, which is a generalization of earlier work by Samuelson is stated explicitly in terms of aggregate social functions and is most directly presented as a dynamic programming problem. In brief, the overall objective function of the problem is

$$(2.18) \quad \max \ E \sum_{t=0}^{T} a_0^t \, [\gamma(q_t) - \xi(s_t - q_t)]$$

subject to

$$(2.19) \quad s_{t-1} = \min \{s_t^{\max}, s_t + z_t - q_t\}$$

where $\gamma(q_t)$ is a concave social utility function with first derivatives $d\gamma/dq_{nt}$, $n = 1, \ldots N$, representing demand functions, $\xi(s_t - q_t)$ is a convex storage cost function for consumers with first derivatives $d\xi/ds_{nt}$, $n = 1, \ldots, N$ representing supply functions, a_0 is a discount factor, and s_t^{max} is the maximum storage capacity available in t. The quantity demanded, q_t, and inventory stocks, s_t, are control variables. The quantity produced, z_t, is assumed to be a stochastic state variable which occurs with probability $P_{kt}(z_{kt})$ in t. The objective is to maximize expected net social product, which is the difference between social utility, $\gamma(q_t)$, and social cost, $\xi(s_t - q_t)$.

As in Section 4.3 the returns function at any stage of the problem is represented in terms of the Lagrangian

$$(2.20)\quad L(s_t, q_t, \lambda_t) = \sum_{k=1}^{K} P_{kt}(z_{kt}) \cdot \; [\gamma(q_t) - \xi(s_t - q_t) + \lambda_t(s_{t-1} - \min\{s_t^{max}, s_t + z_t - q_t\})]$$

and the overall objective function for the problem is described by the recursive relation

$$(2.21)\quad E[f_t(z_t)] = \max_{s_t,\, q_t} \{L(s_t, q_t, \lambda_t) + E[f_{t-1}(z_{t-1})]\}$$

$$t = 1, \ldots, T$$

where $f_t(z_t)$ represents the value of the stage returns function in t.

The principal difference between the expected net social product maximization approach and that of the theory of storage, and inventory and production theory, is that the former is expressed in terms of market aggregates while the latter are formulated in terms of individual firms. Also the expected net social product approach considers the consumers' side of the problem while inventory and production theory and the theory of storage are concerned strictly with the behavior of producers. In addition, one other difference between the expected net social product approach and the two approaches discussed previously is that production is assumed to be the state variable in the former, while the latter regards production as a control variable. These differences are summarized in Table 2.1.

Table 2.1. A Summary of Discrete Dynamic Theories of Market Equilibrium

Theory or Approach	Time Dimension	Aggregation Level	Control Variables	State Variables	Objective
Classical Theory	Static	Individuals and Firms	Output quantity	Prices	Utility and profit maximization
Theory of Storage	Dynamic	Individuals and Firms	Inventory-stocks quantity	Prices	Expected profit maximization
Operations Research Approach	Dynamic	Individuals and Firms	Production quantity	Inventory-stocks quantity	Expected profit maximization
Net Social Product Approach	Dynamic	Market	Inventory-stocks, output quantity	Production quantity	Expected net social profit maximization

3. A THEORY OF DISCRETE DYNAMIC MARKET EQUILIBRIUM

The discrete dynamic theories of price formation discussed in Section 2 consider important problems associated with discrete dynamic market equilibrium. The theory of storage establishes the conditions for equilibrium in the market for stored commodities. Production and inventory theory provides decision rules for firms facing stochastic demand. The expected net social product maximization approach provides a method for determining storage quantities which maximize social welfare. But none of these approaches offers a substantive framework for analyzing market dynamics in a world of multiple market interaction. The theory of storage provides a framework for analyzing firm stocks, but explicitly omits a role for firm production--production is treated as a state variable. Production and inventory theory treat firm production as a decision variable, but take inventory stocks as a stochastic state variable. The expected net social product approach assumes that production is a stochastic state variable, and, because of its aggregate social utility and cost functions, seems virtually impossible to utilize in applied economics.

In the subsections which follow a discrete dynamic theory of market equilibrium is presented. The presentation is straightforward and serves as a foundation for the empirical analysis which follows in the remainder of the dissertation. The theory discussed considers both firm production and inventory levels as subject to control and allows consumers to hold stocks of goods. Section 3.1 presents a theory of the discrete dynamic behavior of firms. Section 3.2 discusses the behavior of consumers and describes the resulting market equilibrium when both firms and consumers make decisions simultaneously.

3.1. Behavior of Firms

In the classical static model of firm behavior there is no provision made for the holding of stocks of goods over time by firms. The firm is assumed to simply sell all that it produces in period t at the prevailing market price. In the real world firms hold stocks. For this reason, any dynamic theory of firm behavior must explain the determination of both production and stock levels of the firm. Discrete single period profit maximization cannot adequately explain firm holdings of stocks and production. This problem is overcome in the discussion presented here by assuming that firms simultaneously maximize profit and expected profit in period t. The result is a generalized discrete dynamic model of firm behavior.

Consider the supply of goods by the firm in period t. To meet demand in t, goods may be produced by the firm in t, or alternatively, drawn from stocks of goods held in t but produced in periods prior to t. The acknowledgement of this dual source of supply is fundamental to the development of a dynamic theory of the firm. In this section, as in Section 2, the dual sources of supply are defined by the basic supply identity

$$(3.1)\quad q_t = s_{t-1} - s_t + z_t$$

where q_t is an Nx1 vector of goods supplied by the firm in t, s_t is an Nx1 vector representing the quantity of goods stored by the firm at the end of t, and z_t is an Nx1 vector representing the quantity of goods produced by the firm in t.

The objective of the firm is assumed to be

$$(3.2) \quad \max \sum_{t=1}^{T} [h_t + E(h_{t+1})]$$

subject to

$$(3.3) \quad \phi(s_t, z_t, x_t) = 0$$

where h_t is a scalar representing profit in period t, $\phi(\ldots)$ is a twice differentiable production function, and x_t is an Mx1 vector of input quantities. Relation (3.2) implies that in any period the objective of the firm is to maximize profit in t and expected profit in t + 1. The satisfaction of this objective requires that firm decisions must be made simultaneously on the level of production in t, which contributes to profit in t, and on the level of stocks which are to be carried into t + 1, which contributes to profit in t + 1.

The constrained problem for any period t requires the maximization of the Lagrangian function

$$(3.4) \quad L(s_t, z_t, x_t, \lambda) = p_t' (s_{t-1} - s_t + z_t) - v'x_t + E(p_{t+1})$$

$$[s_t - E(s_{t+1}) + E(z_{t+1})] - [E(v_{t+1})]' E(x_{t+1}) + \lambda\phi(s_t, z_t, x_t).$$

The necessary conditions for a maximum require

$$(3.5) \quad dL/ds_{nt} = -p_{nt} + E(p_{nt+1}) + \lambda d\phi/ds_{nt} = 0 \qquad n = 1, \ldots, N$$

$$(3.6) \quad dL/dz_{nt} = p_{nt} + \lambda d\phi/dz_{nt} = 0 \qquad n = 1, \ldots, N$$

(3.7) $dL/dx_{mt} = -v_{mt} + \lambda d\phi/dx_{mt} = 0 \qquad m = 1, \ldots, M$

(3.8) $dL/d\lambda = \phi(s_t, z_t, x_t) = 0$

The solution for the level of the control vectors, when it exists, is of the form

(3.9) $s^*_{nt} = \iota[p_t, v_t, E(p_{t+1})] \qquad n = 1, \ldots, N$

(3.10) $z^*_{nt} = \rho[p_t, v_t, E(p_{t+1})] \qquad n = 1, \ldots, N$

(3.11) $x^*_{mt} = \psi[p_t, v_t, E(p_{t+1})] \qquad m = 1, \ldots, M$

(3.12) $\lambda^* = \xi[p_t, v_t, E(p_{t+1})]$

where (3.9) is the inventory-stock relation, (3.10) is the production-flow relation, and (3.11) is the derived demand relation. Sufficient conditions for a maximum require that the determinants of the appropriate principal minors alternate in sign.

By using the backward numbering system and by specifying that each time period corresponds to a stage of a sequential optimization problem, a complete solution to (3.2) can be expressed as a dynamic programming problem in terms of the recursive relation

(3.13) $f_t\,[E(p_{t+1})] = \max_{s_t,\, z_t,\, x_t} \{L(s_t, z_t, x_t, \lambda) + f_{t-1}[E(p_t)]\}$

$t = T, \ldots, 1$

where (3.1) serves as the stage transformation function.

Two results from the determination of the necessary conditions for single period maximization are important. First, the only expected value which enters the solution is $E(p_{t+1})$. Hence the only variable for which a discrete probability distribution must be specified is $E(p_{t+1})$. All of the remaining expected values drop out of the solution. Second, the necessary conditions given in (3.5) through (3.8) state the familiar marginal product conditions of classical economic theory in a general form. This can be demonstrated more clearly by defining the existence of two production functions, $s_t = \phi_1 (x_t^1)$ and $z_t = \phi_2 (x_t^2)$, which represent stock maintenance and production flow functions; by defining the existence of two associated Lagrangian multipliers, λ_1 and λ_2; by substituting in (3.4); and by reoptimizing to obtain the necessary conditions;

$$(3.14) \quad dL/ds_{nt} = -p_{nt} + E(p_{nt+1}) + \lambda_1 = 0 \qquad n = 1, \ldots, N$$

$$(3.15) \quad dL/dz_{nt} = -p_{nt} + \lambda_2 = 0 \qquad n = 1, \ldots, N$$

$$(3.16) \quad dL/dx_{mt}^1 = -v_{mt}^1 - \lambda_1 \; d\phi_1/dx_{mt}^1 = 0 \qquad m = 1, \ldots, M^1$$

$$(3.17) \quad dL/dx_{mt}^2 = -v_{mt}^2 - \lambda_2 \; d\phi_2/dx_{mt}^2 = 0 \qquad m = 1, \ldots, M^2$$

Substitution for the Lagrangian multipliers leads to

$$(3.18) \quad [E(p_{n,t+1}) - p_{nt}] \; d\phi_1/dx_{mt}^1 = v_{mt}^1 \qquad m = 1, \ldots, M^1$$

$$(3.19) \quad p_{nt} \cdot d\phi^2/dx_{mt}^2 = v_{mt}^2 \qquad m = 1, \ldots, M^2$$

The firm maximizing profit and expected profit in t equates the value of the marginal product of storage (the left-hand side of 3.18) to the input price for all inputs used in storage and the value of the marginal product of production (the left-hand side of 3.19) to the input price for all inputs used in production.

The basic single period model given in (3.4) may be augmented by assuming that the firm does not know the probability distribution of $E[p_{t+1}]$ and uses a simple expectations model for extrapolation. The most commonly used models of expectation formation are the Metzler-Ferber extrapolative model, which is written as

$$\text{(3.20)} \quad p^E_{t+1} = \alpha_0 + p_t\ [\alpha_1 + \alpha_2\ (p_t - p_{t-1})/p_{t-1}],$$

and the Cagan-Nerlove adaptive model which is written as

$$\text{(3.21)} \quad p^E_{t+1} = \alpha_0 + \alpha_1\ [\alpha_2 p_t - p^E_t] + p^E_t$$

where the superscript ^{E} denotes an expected or forecast price, and the α_i's are parameters. Both of these expressions may be made stochastic and are discussed in an experimental study of expectation formation by Schmalensee [58]. The substitution of either (3.20) or (3.21) in (3.9) through (3.12) for $E(p_{t+1})$ leads to inventory-stock, production-flow, and derived demand functions which are dependent on past prices.

But an appeal to expectations models is not necessary in order to dynamize the inventory-stock, production-flow, and derived demand functions in (3.9) through (3.11). This is because a basic property of probabilistic dynamic programming problems is that the solution in any stage is conditioned on solution values obtained from previous stages. For this reason (3.9) through (3.11) may be written more generally as

$$(3.22)\quad s^*_{nt} = \iota[p_t, v_t, E(p_{t+1}) | s^*_{n,t-1}, \ldots, s^*_{no}; z^*_{n,t-1}, \ldots, z^*_{no}; x_{n,t-1}, \ldots, x^*_{no}] \qquad n = 1, \ldots, N$$

$$(3.23)\quad z^*_{nt} = \rho[p_t, v_t, E(p_{t+1}) | s^*_{n,t-1}, \ldots, s^*_{no}; z^*_{n,t-1}, \ldots, z^*_{no}; x_{n,t-1}, \ldots, x^*_{no}] \qquad n = 1, \ldots, N$$

$$(3.24)\quad x^*_{mt} = \psi[p_t, v_t, E(p_{t+1}) | s^*_{n,t-1}, \ldots, s^*_{no}; z^*_{n,t-1}, \ldots, z^*_{no}; x_{n,t-1}, \ldots, x^*_{no}] \qquad m = 1, \ldots, M.$$

Clearly decisions in t are conditioned on past history. The set of equations (3.9) through (3.11) or (3.22) through (3.24) constitute a dynamic supply system at t for all N.

3.2. Behavior of Consumers and Discrete Dynamic Market Equilibrium

The behavior of consumers is assumed in this section to be represented by an extension of the intertemporal model discussed in Section 2.1. Consumers maximize separable utility functions subject to income constraints and the constraint that through habit formation, $q_t = \tau(q_{t-1})$. The results are individual demand functions of the form given in (2.3) with the addition of $\tau(q_{t-1})$ as a state variable in each function. Other more complex models could be utilized as long as they yield a decision vector q^*_t in terms of prices. A particularly attractive alternative would be the substitution of a multi-period consumer decision model, such as the one developed by Fama [19], which would allow for the storage of goods by consumers. The purpose of the discussion presented here, however, is to describe a model of dynamic behavior which can be easily implemented empirically and which is a sufficiently accurate representation of actual consumer and producer behavior to allow for market simulations under alternative experimental conditions. In this respect, although its use represents a simplification, the choice of the demand function specified in this study represents the best acceptable alternative available.

If aggregation problems are disregarded, the sum of individual demand functions for the nth good over all consumers leads to the corresponding market demand function. Similarly, the sum of inventory-stock, production-flow, and derived demand functions for the nth good over all firms leads to the corresponding market functions. The existence of market equilibrium in the market for the nth good requires that the quantity of the nth good demanded by consumers equal the quantity of the nth good provided by producers. Explicitly, the existence of market equilibrium in a dual supply system for the nth market requires that

$$(3.25)\quad q_{nt} = s_{n,t-1} - s_{nt} + z_{nt}.$$

Relation (3.25) is the aggregate dynamic market equilibrium identity where the variables q_{nt}, s_{nt}, and z_{nt} are now defined to represent the nth elements of the Nx1 vectors representing market clearing quantities, market inventory-stocks, and market production-flows.

Aggregate consumption decisions in the market for the nth good are determined by the relation

$$(3.26)\quad q_{nt} = \delta_n(p_t, y_t, q_{n,t-1})$$

where p_t is now defined to represent an Nx1 vector of market prices, y_t is aggregate income, and $\delta_n(\ldots)$ is an aggregate demand function. Aggregate inventory-stock decisions are determined by the relation

$$(3.27)\quad s_{nt} = \iota_n\,[p_t, v_t, E(p_{t+1}) \mid \ldots]$$

where v_t is an Mx1 vector of market input prices, $E(p_{t+1})$ is an Nx1 vector of expected market output prices in t + 1, and $\iota_n(\ldots)$ is an aggregate inventory-stock function for the nth good. Aggregate production-flow decisions are determined by the relation

$$(3.28)\quad z_{nt} = \rho_n[p_t, v_t, E(p_{t+1}) \mid \ldots]$$

where $\rho_n(\ldots)$ is an aggregate production-flow function for the nth good. Finally, aggregate input decisions are determined by the relation

$$(3.29)\quad x_{mt} = \psi_m\,[p_t, v_t, E(p_{t+1}) \mid \ldots]$$

where x_{mt} is the mth element of an Mx1 vector of aggregate input quantities and $\psi_m(\ldots)$ is the aggregate derived demand function for the mth input.

In the aggregate it is assumed that market equilibrium is established by tatonnement. This implies that the vector of output prices, p_t, is not fixed but varies until (3.25) is satisfied. For this reason, equations (3.25) through (3.87) constitute a simultaneous equation system of four equations with four endogenous variables--q_{nt}, s_{nt}, z_{nt}, and p_{nt}. If the matrix of coefficients on these four variables is nonsingular and the system of equations is linear, then a unique solution exists for q_{nt}, s_{nt}, z_{nt}, and p_{nt} in the aggregate. In addition, in the situation when there are n = 1, ..., N systems of the type specified by equations (3.25) through (3.28), all relations are linear, and the matrix of coefficients on the endogenous variables is nonsingular, then a unique general equilibrium exists.

In summary, by introducing the fundamental dynamic supply identity to characterize the dual sources of supply and by considering the role of expected prices in the firm's decision calculus, discrete dynamic inventory-stock, production-flow and derived demand relations are generated. When these functions are aggregated across firms and combined with an aggregate demand function for the same commodity, a simultaneous equation system results. There exist N such systems in the economy and under the assumption of competition the problem faced by the economy is the sequential solution of these N simultaneous systems over t = 1, ..., T. Each solution represents a discrete dynamic multi-market equilibrium.

4. THE SPECIFICATION OF A MODEL OF THE UNITED STATES VEGETABLE OILSEEDS, OIL, AND OIL PRODUCTS INDUSTRY

This section presents a postulated partial equilibrium, simultaneous equation model of the United States vegetable oilseeds, oil, and oil products industry. The initial specification of the model is based on the theoretical discussion of Sections 2 and 3. Section 4.1 discusses the nature of the markets modeled. Section 4.2 explains the general approach taken for specification, the strategy employed in the estimation of the system model, and elaborates on such factors as data limitations. Section 4.3 presents the specification of the finished product market models. Section 4.4 presents the specification of the finished oil market models. Section 4.5 presents the specification of the semi-finished oil market models. Section 4.6 presents the specification of the oilseed market models. Section 4.7 presents the specification of the meal market models.

4.1. The Principal Markets of the United States Vegetable Oilseeds, Oil and Oil Products Industry

For purposes of definition, the United States vegetable oilseeds, oil, and oil products industry is defined in this study to consist of five product classes. These are finished food products which include vegetable oil or vegetable oilseeds as their principal ingredient, finished vegetable oil, semi-finished vegetable oil, vegetable oilseeds, and vegetable meal. The first four of these product classes represent a closed end sequential production system--vegetable oilseeds are inputs in the production of semi-finished vegetable oil, semi-finished vegetable oil is an input in the production of finished vegetable oil, and finished vegetable oil is an input in the production of finished food products. Vegetable meal is a joint product with semi-finished vegetable oil from the processing of oilseeds.

The finished food products of the vegetable oil industry, the first of the five product classes of the industry, include six major products. These are cooking oil, shortening, margarine, mayonnaise, salad dressings, and peanut butter. Cooking oil and shortening consist entirely of vegetable oil with only a few chemical preservatives added to the basic product. The ingredients of margarine, according to federal standards of identity, must consist of at least 80 percent vegetable oil. Mayonnaise and salad dressing, according to federal standards, consist of at minimum 60 and 35 percent vegetable oil, respectively. Peanut butter consists of not more than 55 percent oil equivalent. The actual percentages of oil found in these products on the market differs from those bounds, however. The typical oil content is approximately 81, 80, 40, and 50 percent for margarine, mayonnaise, salad dressing, and peanut butter, respectively.

The second class of products of the industry, finished oils, consist of seven principal products. These are finished soybean, cottonseed, coconut, corn, peanut, palm, and safflower oil. Finished vegetable oil is semi-finished oil which has been refined, bleached, deodorized, and possibly hydrogenated or winterized to make the crude oil suitable for use in finished products. Finished soybean oil is used in all finished oil food products, while finished cottonseed oil is used mostly in cooking oil and margarine. Finished peanut oil is used principally in cooking oil and peanut butter, while finished coconut and palm oil are used mainly in shortening.

The third class of products of the industry, semi-finished oils, consist of the same seven oils of the finished oils class. Semi-finished soybean, cottonseed, coconut, peanut, palm, and safflower oil are produced by mechanically crushing or chemically processing soybeans, cottonseed, copra, peanuts, palms, or safflower seeds. Coconut and palm semi-finished oil are imported. Semi-finished corn oil is produced by a wet milling process. Virtually all semi-finished oil is used as the principal raw ingredient of finished oil, although, some semi-finished oil is used in the production of inedible industrial products.

Oilseeds, the fourth product class, must be mechanically crushed or chemically processed to separate semi-finished vegetable oil from the solid matter of the seed. The residual following oil removal is vegetable meal. In general, processed soybeans yield about 18 percent oil, while cottonseed, corn, peanuts, and safflower seed yield around 16, 4, 31, and 36 percent, respectively. Copra and palm kernels, which have been imported and processed domestically, yield approximately 64 and 47 percent oil, respectively. Vegetable meal, the fifth industry product class, is used chiefly as animal feed, with the exception of dry milled corn meal, which is generally utilized for human consumption.

This discussion of the domestic vegetable oilseeds, vegetable oil, and vegetable oil products industry has been limited, principally because there has been a great deal of descriptive literature published about the industry. The interested reader is referred to Swern [60] and Weiss [78] for a technical discussion of the industry. More general descriptive material is available from Lamm [35, 36, 37, 38] and Lopez [43]. The prime source of descriptive statistics on the industry is available from the Economic Research Service [68, 69, 73].

4.2. The General Approach to the Model Specification

Initially it was desired to include in the model all of the vegetable oil and vegetable oil product markets described in the previous section. An inspection of the model flow diagram presented in Figure 4.1 indicates that this was not done, however, because of the limited availability of the necessary monthly data for many variables. Quantity data were not available for the finished products mayonnaise and salad dressing, nor for the finished oil markets with the exception of soybean and cottonseed oil. Also there were insufficient quantity and price data for finished and semi-finished safflower oil, several vegetable meals, and some oilseeds. All of these variables necessarily were eliminated from consideration in the model specification. The consequences of these omissions were small, however, since the excluded products constituted only approximately 6 percent of the total market in terms of sales value. A sufficient monthly data base existed so that the most important products of the industry could be included in the model.

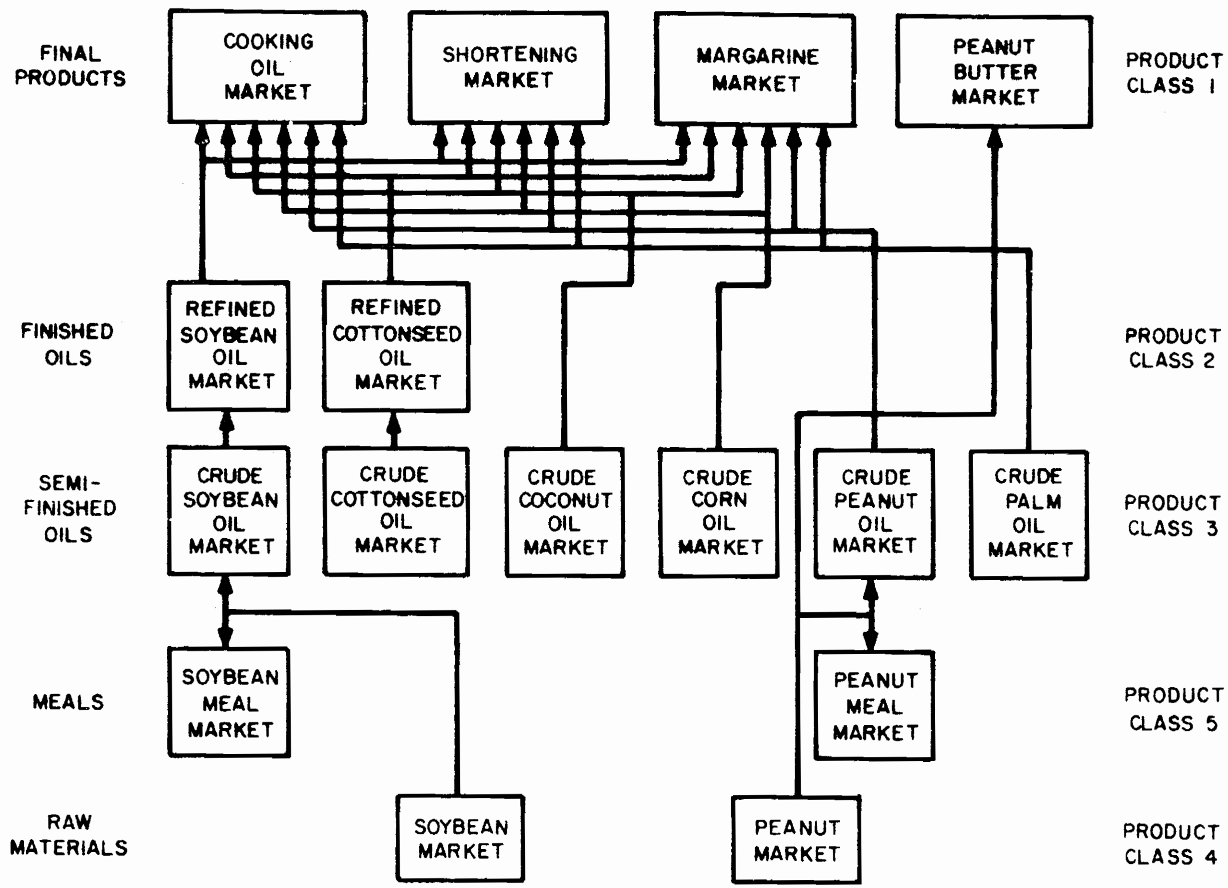

Figure 4.1. A Flow Diagram of the Markets Included in the Model

After eliminating certain markets and variables because of data limitations, the approach taken to specifying the initial form of the model was to take the simultaneous equation system developed in Section 3.2 as a theoretical foundation for each market and then specify, on the basis of subjective appraisal, the appropriate industry variables corresponding to the theoretical variables which were to be included in the demand, the inventory-stock, the production flow, and the derived demand relations for each market. Hence, the initial model specification which follows in Sections 4.3 through 4.7, is dependent on the theoretical exposition in Section 3 for the equation forms and the list of candidate variables for inclusion in each relation.

An important problem which must be considered in the specification of any simultaneous equation model is the role of the regression strategy to be used for statistically selecting the empirical specification of the model. Many analysts approach the simultaneous equation problem by first extending or reducing the set of explanatory variables to a statistically significant set using ordinary least squares (OLS). The significant set of variables is then utilized in the simultaneous equation model specification and estimated using three stage least squares (3SLS). The problem with this approach is that simultaneous equation bias in the OLS estimates may lead to the exclusion of some variables which should be in the model. This leads to specification bias in the 3SLS estimates. Also, if there are statistical problems with the OLS estimates, such as multicollinearity, the use of the standard statistical tests leads to imprecise results and it becomes unclear which variables should be eliminated and which ones should be maintained (see Theil [63] for a discussion of this problem).

An alternative regression strategy for determining the statistical specification of a simultaneous equation model would be to begin estimation using the appropriate simultaneous equation estimation technique. However, this approach can be expensive in terms of computer time. Also, problems arise when the researcher attempts to exclude variables from the model (or add variables) since there is joint dependence across equations. Removing an insignificant variable from one equation may lead to the insignificance of other variables when the model is re-estimated by system methods.

In this study the hypothesized simultaneous equation model presented in the following sections is taken as the initial specification of the industry model. Although it became apparent in the early stages of estimation that some price variables included as current variables in the model might be included as lagged variables, thus breaking up the simultaneity of the system, the current variables were retained under the presumption that current and lagged monthly prices were so highly correlated that it would make little difference if this alternative was pursued. This presupposition proved invalid, however, with the simultaneous model failing to satisfy stability conditions when estimated by OLS, subsystem 3SLS, or 3SLS. For this reason, a transformation strategy was utilized to empiricize the simultaneous equation model by including the appropriate lagged variables. For purposes of information, the results of estimating the simultaneous equation system discussed in this section are presented in Appendix A. The methodology utilized to transform the theoretical system into a final empirical form is discussed in Section 5, while the final form of the empirical model is presented in Section 6. The theoretical specification of the system given in the following subsections is presented to link the theoretical discussion of Sections 2 and 3 with the empirical discussion of Section 6.

4.3. Finished Product Markets in the Model

In the discussion which follows the notational scheme utilized is basically an extension of that developed in Sections 2 and 3. The variable $q_{ij}(t)$ is defined to represent the equilibrium quantity of the ith good in the jth product class in period t. The variable s_{ij} (t) represents the quantity of the ith good in the jth product class stored from the end of t-1 to the end of t. The variable $z_{ij}(t)$ represents the quantity of the ith good in the jth product class produced in period t. The variable $p_{ij}(t)$ represents the price of the ith good in the jth product class in period t. The functions $\delta_{ij}(\ldots)$, $\iota_{ij}(\ldots)$, $\rho_{ij}(\ldots)$, and $\psi_{ij}(\ldots)$ are defined to represent the demand, inventory-stock, production flow, and derived demand functions for the ith good in the jth product class. There are five product classes: finished products, finished oils, semi-finished oils, oilseeds and meals. The subscript j = 1, ..., 5 for each of these classes respectively. The number of goods in each product class is i = 1, ..., Ij.

Four finished products are considered in product class 1 of the basic model. These are cooking oil, shortening, margarine, and peanut butter. The initial theoretical specification of the cooking oil market is:

(4.1) $q_{11}(t) = s_{11}(t-1) - s_{11}(t) + z_{11}(t)$

(4.2) $q_{11}(t) = \delta_{11}\ [p_{11}(t),\ p_{21}(t),\ y(t),\ q_{11}(t-1),\ q_{81}(t)]$

(4.3) $s_{11}(t) = \iota_{11}\ [p_{11}(t),\ p_{71}(t),\ s_{11}(t-1),\ z_{11}(t-1)]$

(4.4) $z_{11}(t) = \rho_{11}\ [p_{11}(t),\ p_{12}(t),\ s_{11}(t-1),\ z_{11}(t-1)]$

(4.5) $q_{12}^{(1)}(t) = \psi_{12}^{(1)}\ [p_{11}(t),\ p_{12}(t),\ s_{11}(t-1),\ z_{11}(t-1),\ q_{12}^{(1)}(t-1)]$

(4.6) $q_{22}^{(1)}(t) = \psi_{22}^{(1)}\ [p_{11}(t),\ p_{22}(t),\ s_{11}(t-1),\ z_{11}(t-1),\ q_{22}^{(1)}(t-1)]$

(4.7) $q_{33}^{(1)}(t) = \psi_{33}^{(1)}\ [p_{11}(t),\ p_{33}(t),\ s_{11}(t-1),\ z_{11}(t-1),\ q_{33}^{(1)}(t-1)]$

(4.8) $q_{43}^{(1)}(t) = \psi_{43}^{(1)}\ [p_{11}(t),\ p_{43}(t),\ s_{11}(t-1),\ z_{11}(t-1),\ q_{43}^{(1)}(t-1)]$

(4.9) $q_{53}^{(1)}(t) = \psi_{53}^{(1)}\ [p_{11}(t),\ p_{53}(t),\ s_{11}(t-1),\ z_{11}(t-1),\ q_{53}^{(1)}(t-1)]$

(4.10) $q_{63}^{(1)}(t) = \psi_{63}^{(1)}\ [p_{11}(t),\ p_{63}(t),\ s_{11}(t-1),\ z_{11}(t-1),\ q_{63}^{(1)}(t-1)]$.

Relation (4.1) is the dynamic market equilibrium identity, (4.2) is the demand function for cooking oil, (4.3) is the inventory-stock function for cooking oil, (4.4) is the production-flow function for cooking oil, and relations (4.5) through (4.10) are the derived demand functions for refined soybean oil, refined cottonseed oil, crude coconut oil, crude corn oil, crude peanut oil, and crude palm oil used in cooking oil. The variable $y(t)$ represents income in t and $p_{71}(t)$ is the commercial paper rate in t. Figure 4.2 presents a diagram illustrating the structure of the finished products market model. Table 4.1 defines all of the variables discussed in this section.

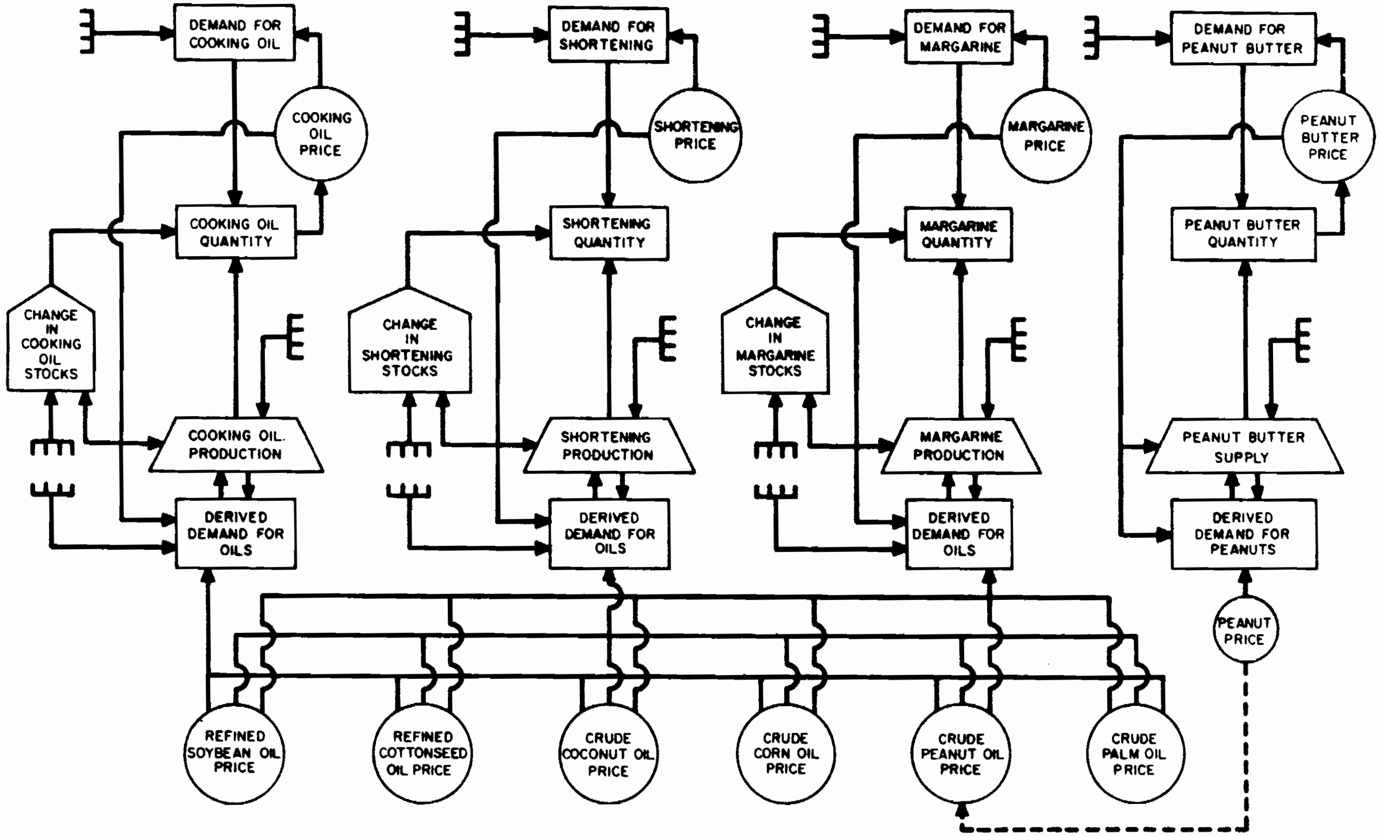

Figure 4.2. A Diagrammatic Representation of the Finished Products Market Model

Table 4.1. Definitions of Variables in the Model

Number	Symbol	Definition	Unit of Measure
		Endogenous Variables	
1	q_{11}	domestic disappearance of cooking oil	1000 lbs.
2	s_{11}	stocks of cooking oil	1000 lbs.
3	z_{11}	production of cooking oil	1000 lbs.
4	p_{11}	price of cooking oil	¢/lb. x 100
5	q_{21}	domestic disappearance of shortening	1000 lbs.
6	s_{21}	stocks of shortening	1000 lbs.
7	z_{21}	production of shortening	1000 lbs.
8	p_{21}	price of shortening	¢/3 lbs. x 100
9	q_{31}	domestic disappearance of margarine	1000 lbs.
10	s_{31}	stocks of margarine	1000 lbs.
11	z_{31}	production of margarine	1000 lbs.
12	p_{31}	price of margarine	¢/lb. x 100
13	$q_{12}^{(1)}$	quantity of soybean oil used in cooking oil	1000 lbs.
14	$q_{22}^{(1)}$	quantity of cottonseed oil used in cooking oil	1000 lbs.
15	$q_{33}^{(1)}$	quantity of coconut oil used in cooking oil	1000 lbs.
16	$q_{43}^{(1)}$	quantity of corn oil used in cooking oil	1000 lbs.
17	$q_{53}^{(1)}$	quantity of peanut oil used in cooking oil	1000 lbs.

Table 4.1. Continued

Number	Symbol	Definition	Unit of Measure
		- - - - - - - - - - - - Endogenous Variables - - - - - - - - - - - - - -	
18	$q_{63}^{(1)}$	quantity of palm oil used in cooking oil	1000 lbs.
19	$q_{12}^{(2)}$	quantity of soybean oil used in shortening	1000 lbs.
20	$q_{22}^{(2)}$	quantity of cottonseed oil used in cooking oil	1000 lbs.
21	$q_{33}^{(2)}$	quantity of coconut oil used in shortening	1000 lbs.
22	$q_{43}^{(2)}$	quantity of corn oil used in shortening	1000 lbs.
23	$q_{53}^{(2)}$	quantity of peanut oil used in shortening	1000 lbs.
24	$q_{63}^{(2)}$	quantity of palm oil used in shortening	1000 lbs.
25	$q_{12}^{(3)}$	quantity of soybean oil used in margarine	1000 lbs.
26	$q_{22}^{(3)}$	quantity of cottonseed oil used in margarine	1000 lbs.
27	$q_{33}^{(3)}$	quantity of coconut oil used in margarine	1000 lbs.
28	$q_{43}^{(3)}$	quantity of corn oil used in margarine	1000 lbs.
29	$q_{53}^{(3)}$	quantity of peanut oil used in margarine	1000 lbs.
30	$q_{63}^{(3)}$	quantity of palm oil used in margarine	1000 lbs.
31	p_{12}	price of refined soybean oil	¢/lb. x 100

Table 4.1. Continued

Number	Symbol	Definition	Unit of Measure
		Endogenous Variables	
32	p_{22}	price of refined cottonseed oil	¢/lb. x 100
33	p_{33}	price of crude coconut oil	¢/lb. x 100
34	p_{43}	price of crude corn oil	¢/lb. x 100
35	p_{53}	price of crude peanut oil	¢/lb. x 100
36	p_{63}	price of crude palm oil	¢/lb. x 100
37	s_{12}	stocks of refined soybean oil	1000 lbs.
38	z_{12}	production of refined soybean oil	1000 lbs.
39	s_{22}	stocks of refined cottonseed oil	1000 lbs.
40	z_{22}	production of refined cottonseed oil	1000 lbs.
41	q_{13}	domestic disappearance of crude soybean oil	1000 lbs.
42	q_{23}	domestic disappearance of crude cottonseed oil	1000 lbs.
43	p_{13}	price of crude soybean oil	¢/lb. x 100
44	p_{23}	price of crude cottonseed oil	c/lb. x 100
45	s_{13}	stocks of crude soybean oil	1000 lbs.
46	z_{13}	production of crude soybean oil	1000 lbs.
47	q_{14}	quantity of soybeans processed	1000 lbs.

Table 4.1. Continued

Number	Symbol	Definition	Unit of Measure
		Endogenous Variables	
48	p_{14}	price of soybeans	¢/bu.
49	s_{23}	stocks of crude cottonseed oil	1000 lbs.
50	z_{23}	production of crude cottonseed oil	1000 lbs.
51	s_{33}	stocks of crude coconut oil	1000 lbs.
52	s_{43}	stocks of corn oil	1000 lbs.
53	s_{53}	stocks of peanut oil	1000 lbs.
54	z_{53}	production of peanut oil	1000 lbs.
55	q_{54}	quantity of peanuts processed	1000 lbs.
56	p_{54}	price of peanuts	¢/lb. x 100
57	s_{63}	stocks of palm oil	1000 lbs.
58	s_{14}	stocks of soybeans	1000 bu.
59	s_{54}	stocks of peanuts	1000 lbs.
60	s_{15}	stocks of soybean meal	1000 tons
61	p_{15}	price of soybean meal	¢/ton
62	z_{15}	production of soybean meal	1000 tons
63	s_{55}	stocks of peanut meal	1000 tons
64	p_{55}	price of peanut meal	¢/ton
65	z_{55}	production of peanut meal	1000 tons
66	q_{91}	domestic disappearance of peanut butter	1000 lbs.

Table 4.1. Continued

Number	Symbol	Definition	Unit of Measure
		Endogenous Variables	
67	p_{91}	price of peanut butter	¢/lb. x 100
		Exogenous Variables	
1	p_{41}	price of lard	¢/lb. x 100
2	p_{51}	price of butter	¢/lb. x 100
3	e_{12}	quantity of refined soybean oil used in other products	1000 lbs.
4	e_{22}	quantity of refined cotton-seed oil used in other products	1000 lbs.
5	e_{13}	net exports of crude soybean oil	1000 lbs.
6	$E[p_{13}(t)]$	future prices of crude soybean oil	¢/lb.
7	$e_{23}(t)$	net exports of crude cottonseed oil	1000 lbs.
8	$p_{24}(t)$	price of cottonseed	¢/ton
9	$e_{32}(t)$	quantity of crude coconut oil used in other products	1000 lbs.
10	$z_{33}(t)$	production of crude coconut oil	1000 lbs.
11	$e_{43}(t)$	quantity of crude corn oil used in other products	1000 lbs.
12	$z_{43}(t)$	production of crude corn oil	1000 lbs.
13	$e_{63}(t)$	quantity of crude peanut oil used in other products	1000 lbs.

Table 4.1. Continued

Number	Symbol	Definition	Unit of Measure
		Exogenous Variables	
14	$e_{63}(t)$	quantity of crude palm oil used in other products	1000 lbs.
15	$z_{63}(t)$	production of crude palm oil	1000 lbs.
16	$z_{14}(t)$	production of soybeans	1000 bu.
17	$e_{14}(t)$	production minus other uses of soybeans (other than crushing)	1000 bu.
18	$E[p_{14}(t)]$	future prices of soybeans	¢/bu.
19	$z_{54}(t)$	production of peanuts	1000 lbs.
20	$e_{54}(t)$	other uses of peanuts (other than crushing)	1000 lbs.
21	$E[p_{15}(t)]$	futures price of soybean meal	¢/ton
22	$q_{15}(t)$	domestic disappearance of soybean meal	1000 tons
23	$q_{55}(t)$	domestic disappearance of peanut meal	1000 lbs.
24	$e_{15}(t)$	net exports of soybean meal	1000 tons
25	$e_{55}(t)$	net exports of peanut meal	1000 lbs.
26	$q_{81}(t)$	population	1000's
27	$p_{71}(t)$	commercial paper rate	% x 100
28	$y(t)$	personal income	$100 million
29	$d_1(t)$	dummy variable for January	binary
30	$d_2(t)$	dummy variable for February	binary
31	$d_3(t)$	dummy variable for March	binary

Table 4.1. Continued

Number	Symbol	Definition	Unit of Measure
		Exogenous Variables	
32	$d_4(t)$	dummy variable for April	binary
33	$d_5(t)$	dummy variable for May	binary
34	$d_6(t)$	dummy variable for June	binary
35	$d_7(t)$	dummy variable for July	binary
36	$d_8(t)$	dummy variable for August	binary
37	$d_9(t)$	dummy variable for September	binary
38	$d_{10}(t)$	dummy variable for October	binary
39	$d_{11}(t)$	dummy variable for November	binary
40	$g_{13}(t)$	foreign donations of soybean oil	1000 lbs.
41	$g_{23}(t)$	foreign donations of cottonseed oil	1000 lbs.
42	$g_{33}(t)$	change in bonded stocks of coconut oil	1000 lbs.
43	$g_{14}(t)$	change in government stocks of soybeans	1000 bu.
44	$g_{54}(t)$	change in government stocks of peanuts	1000 lbs.
45	$g^L_{33}(t)$	level of bonded stocks of coconut oil	1000 lbs.
46	$g^L_{14}(t)$	level of government stocks of soybeans	1000 bu.
47	$g^L_{15}(t)$	level of government stocks of peanuts	1000 lbs.

The initial theoretical specification of the shortening market is described by the relations

$$(4.11) \quad q_{21}(t) = s_{21}(t-1) - s_{21}(t) + z_{21}(t)$$

$$(4.12) \quad q_{21}(t) = \delta_{21}\ [p_{21}(t),\ p_{11}(t),\ p_{41}(t),\ y(t),\ q_{21}(t-1),\ q_{81}(t)]$$

$$(4.13) \quad s_{21}(t) = \iota_{21}\ [p_{21}(t),\ p_{71}(t),\ s_{21}(t-1),\ z_{21}(t-1)]$$

$$(4.14) \quad z_{21}(t) = \rho_{21}\ [p_{21}(t),\ p_{12}(t),\ s_{21}(t-1),\ z_{21}(t-1)]$$

$$(4.15) \quad q_{12}^{(2)}(t) = \psi_{12}^{(2)}\ [p_{21}(t),\ p_{12}(t),\ s_{21}(t-1),\ z_{21}(t-1),\ q_{12}^{(2)}(t-1)]$$

$$(4.16) \quad q_{22}^{(2)}(t) = \psi_{22}^{(2)}\ [p_{21}(t),\ p_{22}(t),\ s_{21}(t-1),\ z_{21}(t-1),\ q_{22}^{(2)}(t-1)]$$

$$(4.17) \quad q_{33}^{(2)}(t) = \psi_{33}^{(2)}\ [p_{21}(t),\ p_{33}(t),\ s_{21}(t-1),\ z_{21}(t-1),\ q_{33}^{(2)}(t-1)]$$

$$(4.18) \quad q_{43}^{(2)}(t) = \psi_{43}^{(2)}\ [p_{21}(t),\ p_{43}(t),\ s_{21}(t-1),\ z_{21}(t-1),\ q_{43}^{(2)}(t-1)]$$

$$(4.19) \quad q_{53}^{(2)}(t) = \psi_{53}^{(2)}\ [p_{21}(t),\ p_{53}(t),\ s_{21}(t-1),\ z_{21}(t-1),\ q_{53}^{(2)}(t-1)]$$

$$(4.20) \quad q_{63}^{(2)}(t) = \psi_{63}^{(2)}\ [p_{21}(t),\ p_{63}(t),\ s_{21}(t-1),\ z_{21}(t-1),\ q_{63}^{(2)}(t-1)].$$

where $p_{41}(t)$ is the price of lard and the other variables are defined as for cooking oil. Relation (4.11) is the dynamic market equilibrium identity for shortening, (4.12) is the demand function for shortening, (4.13) is the inventory-stock function for shortening, (4.14) is the production flow function for shortening, and relations (4.15) through (4.20) are the derived demand functions for refined soybean oil, refined cottonseed oil, crude coconut oil, crude corn oil, crude peanut oil, and crude palm oil used in shortening.

The initial theoretical specification of the margarine market is

(4.21) $q_{31}(t) = s_{31}(t-1) - s_{31}(t) + z_{31}(t)$

(4.22) $q_{31}(t) = \delta_{31}\ [p_{31}(t),\ p_{51}(t),\ y(t),\ q_{81}(t-1)]$

(4.23) $s_{31}(t) = \iota_{31}\ [p_{31}(t),\ p_{71}(t),\ s_{31}(t-1),\ z_{31}(t-1)]$

(4.24) $z_{31}(t) = \rho_{31}\ [p_{31}(t),\ p_{12}(t),\ s_{31}(t-1),\ z_{31}(t-1)]$

(4.25) $q_{12}^{(3)}(t) = \psi_{12}^{(3)}\ [p_{31}(t),\ p_{12}(t),\ s_{31}(t-1),\ z_{31}(t-1),\ q_{12}^{(3)}(t-1)]$

(4.26) $q_{22}^{(3)}(t) = \psi_{22}^{(3)}\ [p_{31}(t),\ p_{22}(t),\ s_{31}(t-1),\ z_{31}(t-1),\ q_{22}^{(3)}(t-1)]$

(4.27) $q_{33}^{(3)}(t) = \psi_{33}^{(3)}\ [p_{31}(t),\ p_{33}(t),\ s_{31}(t-1),\ z_{31}(t-1),\ q_{33}^{(3)}(t-1)]$

(4.28) $q_{43}^{(3)}(t) = \psi_{43}^{(3)}\ [p_{31}(t),\ p_{43}(t),\ s_{31}(t-1),\ z_{31}(t-1),\ q_{43}^{(3)}(t-1)]$

(4.29) $q_{53}^{(3)}(t) = \psi_{53}^{(3)}\ [p_{31}(t),\ p_{53}(t),\ s_{31}(t-1),\ z_{31}(t-1),\ q_{53}^{(3)}(t-1)]$

(4.30) $q_{63}^{(3)}(t) = \psi_{63}^{(3)}\ [p_{31}(t),\ p_{63}(t),\ s_{31}(t-1),\ z_{31}(t-1),\ q_{63}^{(3)}(t-1)]$

where $p_{51}(t)$ is the price of butter. Relation (4.21) is the dynamic market equilibrium identity for margarine, (4.22) is the demand function for margarine, (4.23) is the inventory-stock function for margarine, (4.24) is the production-flow function for margarine, and (4.25) through (4.30) are the derived demands for refined soybean oil, refined cottonseed oil, crude coconut oil, crude corn oil, crude peanut oil, and crude palm oil used in margarine.

The absence of any data on monthly peanut butter demand, stocks, and production prohibited the estimation of the simultaneous relations of the peanut butter market. However, sufficient price, and quantity data on the proxy variable "peanuts used in peanut butter" existed so that the specification

$$(4.31) \quad q_{91}(t) = \delta_{91}\ [p_{91}(t),\ y(t),\ q_{81}(t)]$$

$$(4.32) \quad q_{91}(t) = \sigma_{91}\ [p_{91}(t),\ p_{54}(t),\ p_{71}(t),\ q_{91}(t\text{-}1)]$$

could be made. Relation (4.31) is taken as the demand function for peanut butter where $q_{91}(t)$ is the proxy "peanuts used in peanut butter" and $p_{91}(t)$ is the price of peanut butter. Relation (4.32) is the supply function for peanut butter where $p_{54}(t)$ is the price of shelled peanuts.

4.4. Finished Oil Markets in the Model

Two finished oils are considered in product class 2 of the basic model. These are refined soybean and refined cottonseed oil. The initial theoretical specification of the refined soybean oil market is

$$(4.33) \quad \sum_{k=1}^{3} q_{12}^{(k)}(t) + e_{12}(t) = s_{12}(t\text{-}1) - s_{12}(t) + z_{12}(t)$$

$$(4.34) \quad s_{12}(t) = \iota_{12}\ [p_{12}(t),\ p_{71}(t),\ s_{12}(t\text{-}1),\ z_{12}(t\text{-}1)]$$

$$(4.35) \quad z_{12}(t) = \rho_{12}\ [p_{12}(t),\ p_{13}(t),\ s_{12}(t\text{-}1),\ z_{12}(t\text{-}1)]$$

$$(4.36) \quad q_{13}(t) = \psi_{13}\ [p_{12}(t),\ p_{13}(t),\ s_{12}(t\text{-}1),\ z_{12}(t\text{-}1),\ q_{13}(t\text{-}1)]$$

where (4.33) is an identity stating that the demand for refined soybean oil is the sum of the derived demands for refined soybean oil in cooking oil, shortening, and margarine added to a residual derived demand for other uses. This quantity is equivalent to the dynamic market equilibrium identity for refined soybean oil. For the summation, k is set equal to 1, 2, 3 for cooking oil, shortening, and margarine, respectively. Relation (4.34) is the inventory-stock function for refined soybean oil, (4.35) is the production-flow function for refined soybean oil, and (4.36) is the derived demand function for crude soybean oil. A diagrammatic representation of the structure of the finished oil markets model is given in Figure 4.3.

The initial theoretical specification of the refined cottonseed oil market is

$$(4.37)\quad \sum_{k=1}^{3} q_{22}^{(k)}(t) + e_{22}(t) = s_{22}(t-1) - s_{22}(t) + z_{22}(t)$$

$$(4.38)\quad s_{22}(t) = \iota_{22}\ [p_{22}(t),\ p_{71}(t),\ s_{22}(t-1),\ z_{22}(t-1)]$$

$$(4.39)\quad z_{22}(t) = \rho_{22}\ [p_{22}(t),\ p_{23}(t),\ s_{22}(t-1),\ z_{22}(t-1)]$$

$$(4.40)\quad q_{23}(t) = \psi_{23}\ [p_{22}(t),\ p_{23}(t),\ s_{22}(t-1),\ z_{22}(t-1),\ q_{23}(t-1)]$$

where (4.37) is an identity stating that the demand for refined cottonseed oil is the sum of the derived demands for refined cottonseed oil used in cooking oil, shortening, and margarine added to a residual derived demand for other uses. This quantity is equivalent to the dynamic market equilibrium identity for refined cottonseed oil. For the summation, k is set equal to 1, 2, 3 for cooking oil, shortening, and margarine respectively. Relation (4.38) is the inventory-stock function for refined cottonseed oil, (4.39) is the production

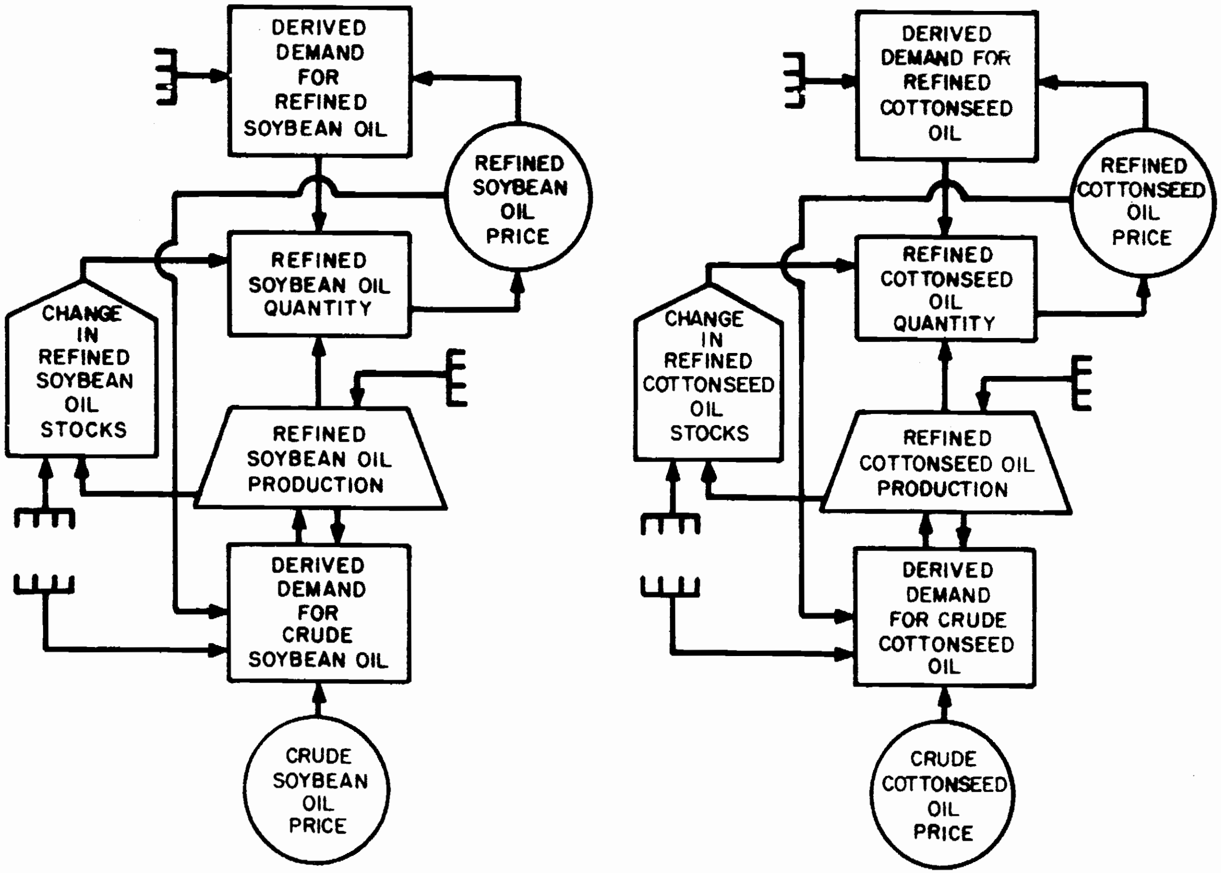

Figure 4.3. A Diagrammatic Representation of the Finished Oils Market Model

flow function for refined cottonseed oil, and (4.40) is the derived demand function for crude cottonseed oil.

4.5. Semi-Finished Oil Markets in the Model

Six semi-finished oils of product class 3 are considered in the basic model. These are crude soybean, cottonseed, coconut, corn, peanut, and palm oil. The output of the crude soybean and cottonseed oil markets maps directly into the finished soybean and cottonseed oil markets as input. The output of the crude coconut, corn, peanut, and palm oil markets is assumed to map directly into the finished product markets as input. A diagrammatic representation of the semi-finished oil markets model is given in Figure 4.4.

The initial theoretical specification of the semi-finished soybean oil market is

$$(4.41)\quad q_{13}(t) = s_{13}(t-1) - s_{13}(t) + z_{13}(t) - e_{13}(t) - g_{13}(t)$$

$$(4.42)\quad s_{13}(t) = \iota_{13}\ [p_{13}(t),\ E\ [p_{13}(t)],\ p_{71}(t),\ s_{13}(t-1),\ z_{13}(t-1)]$$

$$(4.43)\quad z_{13}(t) = \rho_{13}\ [p_{13}(t),\ p_{14}(t),\ s_{13}(t-1),\ z_{13}(t-1)]$$

$$(4.44)\quad q_{14}(t) = \psi_{13}\ [p_{13}(t),\ p_{14}(t),\ p_{15}(t),\ s_{13}(t-1),\ z_{13}(t-1),\ s_{15}(t-1)]$$

where (4.41) is the dynamic market equilibrium identity for semi-finished soybean oil with $e_{13}(t)$ representing net exports and $g_{13}(t)$ representing government foreign donations. Relation (4.42) is the inventory-stock function for crude soybean oil with $E[p_{13}(t)]$

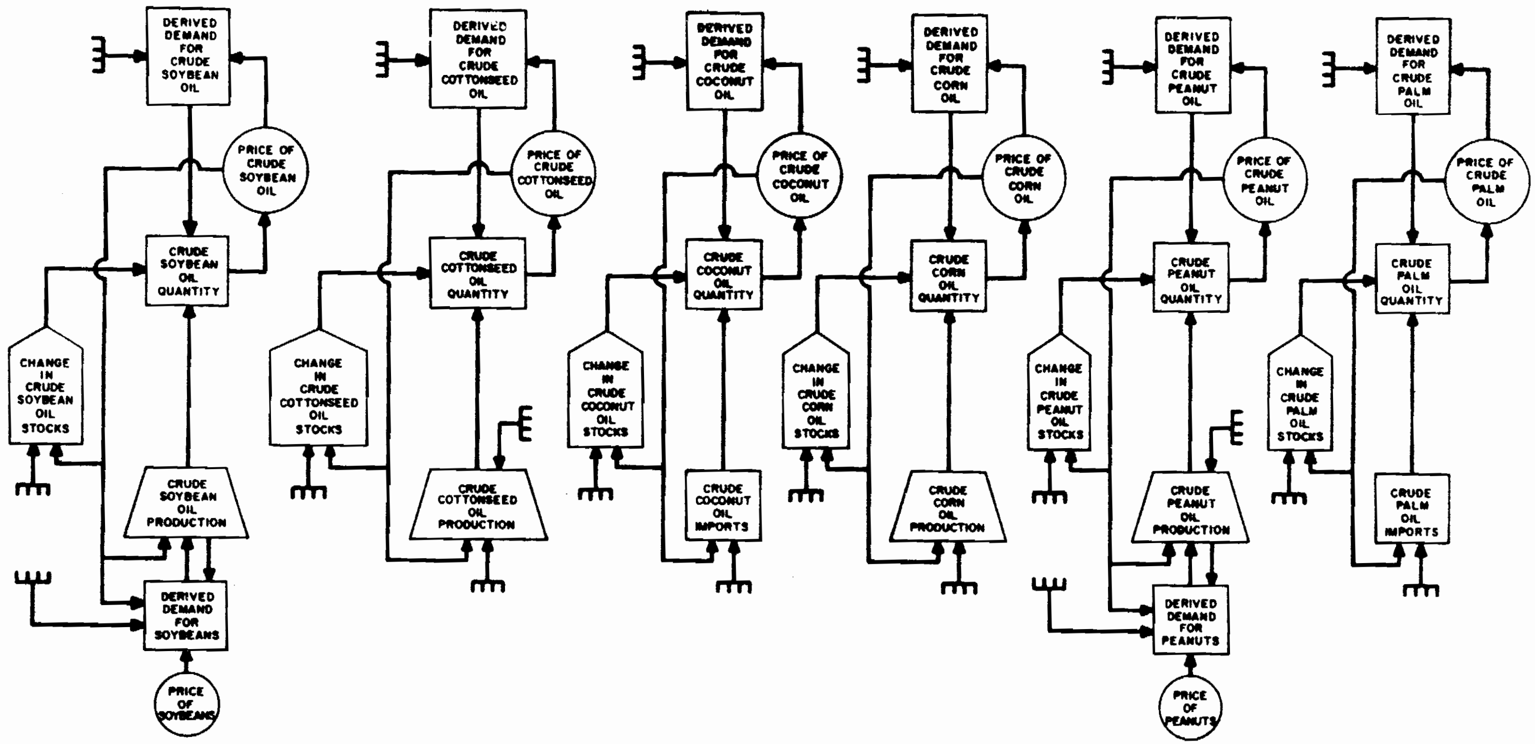

Figure 4.4. A Diagrammatic Representation of the Semi-Finished Oils Market Model

representing the futures price for crude soybean oil, (4.43) is the production-flow function for crude soybean oil, and (4.44) is the derived demand function for processed soybeans. Note that the price of soybean meal, $p_{15}(t)$, and the lagged supply of soybean meal stocks, $s_{15}(t-1)$, enters the derived demand function for processed soybeans since crude soybean oil and soybean meal are joint products, and that the futures price of soybean oil is used to represent the expected price for producers. Throughout this section futures prices are used, when available, to represent producer expectations.

The initial theoretical specification of the semi-finished cottonseed oil market is

$$(4.45)\quad q_{23}(t) = s_{23}(t-1) - s_{23}(t) + z_{23}(t) - e_{23}(t) - g_{23}(t)$$

$$(4.46)\quad s_{23}(t) = \iota_{23}\ [p_{23}(t),\ p_{71}(t),\ s_{23}(t-1),\ z_{23}(t-1)]$$

$$(4.47)\quad z_{23}(t) = \rho\ [p_{23}(t),\ p_{24}(t),\ s_{23}(t-1),\ z_{23}(t-1)]$$

where (4.45) is the dynamic market equilibrium identity for crude cottonseed oil with $e_{23}(t)$ representing net exports and $g_{23}(t)$ representing net government donations. Relation (4.46) is the inventory-stock function for semi-finished cottonseed oil, and (4.47) is the production-flow function for semi-finished cottonseed oil.

For the semi-finished coconut oil market, the initial theoretical specification is

$$(4.48)\quad \sum_{k=1}^{3} q_{33}^{(k)}(t) = s_{33}(t-1) - s_{33}(t) + z_{33}(t) - e_{33}(t) + g_{33}(t)$$

$$(4.49)\quad s_{33}(t) = \iota_{33}\,[p_{33}(t),\ p_{71}(t),\ s_{33}(t-1),\ g^{L}_{33}(t)]$$

where (4.48) is an identity stating that the demand for crude coconut oil is the sum of the derived demands for crude coconut oil used in cooking oil, shortening, and margarine. This quantity is equivalent to the dynamic market equilibrium identity for crude coconut oil with $e_{33}(t)$ representing net exports and residual derived demand quantities. Variable $g_{33}(t)$ represents the change in government bonded stocks of coconut oil from the end of t-1 to the end of t. For the summation, k equals 1, 2, 3 for cooking oil, shortening, and margarine, respectively. Relation (4.49) is the inventory-stock function for semi-finished coconut oil. The production of coconut oil, $z_{33}(t)$ is taken as exogenously determined.

The initial theoretical specification of the semi-finished corn oil market is

$$(4.50)\quad \sum_{k=1}^{3} q^{(k)}_{43}(t) = s_{43}(t-1) - s_{43}(t) + z_{43}(t) - e_{43}(t)$$

$$(4.51)\quad s_{43}(t) = \iota_{43}\,[p_{43}(t),\ p_{71}(t),\ s_{43}(t-1)]$$

where (4.50) is an identity stating that the derived demand for crude corn oil is the sum of the derived demands for crude corn oil used in cooking oil, shortening, and margarine. This quantity is equivalent to the dynamic market equilibrium identity for crude corn oil with $e_{43}(t)$ representing net exports and residual derived demand quantities. The production of crude corn oil, $z_{43}(t)$ is taken as exogenously determined and relation (4.51) represents the inventory-stock function for crude corn oil.

For the semi-finished peanut oil market, the initial theoretical specification is

$$(4.52)\quad \sum_{k=1}^{3} q_{53}^{(k)}(t) = s_{53}(t-1) - s_{53}(t) + z_{53}(t) - e_{53}(t)$$

$$(4.53)\quad s_{53}(t) = \iota_{53}\,[p_{53}(t),\ p_{71}(t),\ s_{53}(t-1),\ z_{53}(t-1)]$$

$$(4.54)\quad z_{53}(t) = \rho_{53}\,[p_{53}(t),\ p_{54}(t),\ s_{53}(t-1),\ z_{53}(t-1)]$$

$$(4.55)\quad q_{54}(t) = \psi_{53}\,[p_{53}(t),\ p_{54}(t),\ s_{53}(t-1),\ z_{53}(t-1),\ q_{54}(t-1),\ p_{55}(t),\ s_{55}(t-1)]$$

where (4.57) is an identity which states that the derived demands for crude peanut oil is the sum of the derived demands for peanut oil used in cooking oil, shortening, and margarine. This quantity is equivalent to the dynamic market equilibrium identity for crude peanut oil with $e_{53}(t)$ representing net exports and residual derived demand quantities. Relation (4.53) is the inventory-stock function for crude peanut oil, (4.54) is the production-flow function for crude peanut oil, and (4.55) is the derived demand function for processed peanuts with $p_{55}(t)$ representing the price of peanut meal and $s_{55}(t-1)$ representing the lagged stocks of peanut meal.

The initial theoretical specification of the semi-finished palm oil market is

$$(4.56)\quad \sum_{k=1}^{3} q_{63}^{(k)}(t) = s_{63}(t-1) - s_{63}(t) + z_{63}(t) - e_{63}(t)$$

$$(4.57)\quad s_{63}(t) = \iota_{63}\,[p_{63}(t),\ p_{71}(t),\ s_{63}(t-1)]$$

where (4.56) is an identity which requires that the derived demand for crude palm oil equal the sum of the derived demands for crude palm oil used in cooking oil, shortening, and margarine. This quantity is equivalent to the dynamic market equilibrium identity for crude palm oil with $e_{63}(t)$ representing net exports and residual derived demand quantities. Relation (4.57) is the inventory-stock function for palm oil.

4.6. Oilseed Markets in the Model

Only two products are included in the model specification of the oilseed markets. These are soybeans and peanuts. Soybeans are the input for both soybean meal and semi-finished oil production, and peanuts are the input for peanut meal and semi-finished peanut oil production. Other raw material markets are excluded from the model because of data limitations, the desire to concentrate on the most important oilseeds market (soybeans), and the desire to include the one major raw material market for oil which is still subject to government price supports (peanuts). A diagrammatic representation of the oilseeds market model is given in Figure 4.5.

The initial theoretical specification of the soybean market is

$$(4.58)\quad q_{14}(t) = s_{14}(t-1) - s_{14}(t) + z_{14}(t) + g_{14}(t) + e_{14}(t)$$

$$(4.59)\quad s_{14}(t) = \iota_{14}\ [p_{14}(t),\ E\ [p_{14}(t)],\ p_{71}(t),\ s_{14}(t-1),\ d_1(t),\ \ldots,\ d_{11}(t),\ g_{14}^{L}(t)]$$

where (4.58) is the dynamic market clearing identity for soybeans with $e_{14}(t)$ representing the quantity of residual uses of soybeans, other

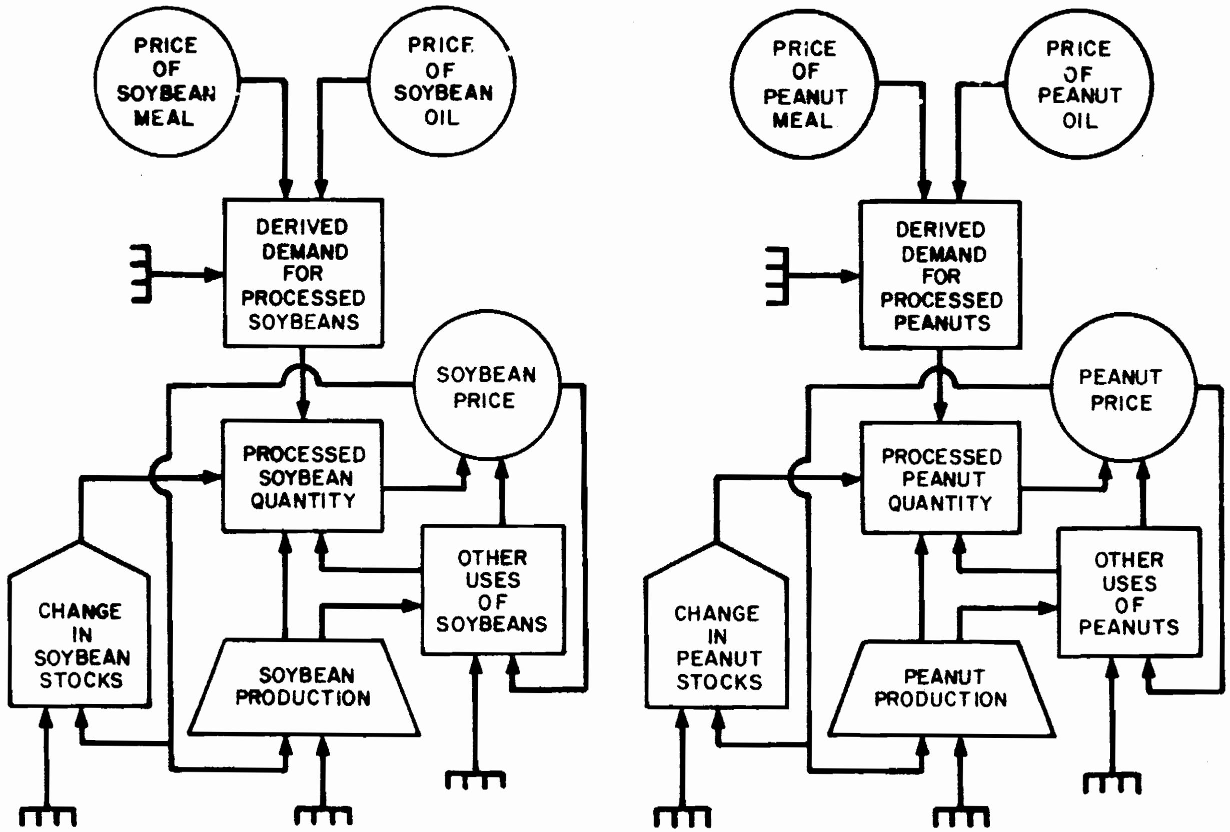

Figure 4.5. A Diagrammatic Representation of the Oilseeds Market Model

than for domestic crushing (net exports, seed, feed, for example), and $g_{14}(t)$ represents the net change in government stocks of soybeans. Relation (4.59) is the inventory-stock function for soybeans. The production of soybeans, $z_{14}(t)$, is taken as an exogenous variable. The variable E $[p_{14}(t)]$ is the futures price of soybeans, $g_{14}^{L}(t)$ is the level of government stocks of soybeans, and the $d_i(t)$ are dummy variables for months.

For the peanut market, the initial theoretical specification is

$$(4.60)\quad q_{54}(t) = s_{54}(t-1) - s_{54}(t) + z_{54}(t) - e_{54}(t) + g_{54}(t)$$

$$(4.61)\quad s_{54}(t) = \iota_{54}\ [p_{54}(t),\ p_{71}(t),\ s_{54}(t-1),\ d_1,\ \ldots,\ d_{11},\ g_{15}^{L}(t)]$$

where (4.60) is the dynamic market clearing identity for peanuts with $e_{54}(t)$ representing the quantity of peanuts used for other purposes than for domestic crushing (net exports, edible peanuts, peanuts in food products), and $g_{54}(t)$ represents the net change in government uncommitted stocks from t-1 to the end of t. Relation (4.61) is the inventory-stock function for peanuts. The production of peanuts, $z_{54}(t)$ is taken as exogenously determined. The variables $d_i(t)$ are dummy variables representing months and $g_{15}^{L}(t)$ is the level of government stocks of peanuts.

4.7. Meal Markets in the Model

Two products are considered in the model specification of the meal markets. These are soybean meal and peanut meal. These products are included in the model to reduce the simultaneous equation bias which might be introduced if only the vegetable oil side of the joint demand for soybeans and peanuts were considered. The initial theoretical specification of the soybean meal market is

$$(4.62)\quad q_{15}(t) = s_{15}(t-1) - s_{15}(t) + z_{15}(t) + e_{15}(t)$$

$$(4.63)\quad s_{15}(t) = \iota_{15}\ [p_{15}(t),\ E\ [p_{15}(t)],\ p_{71}(t),\ s_{15}(t-1),\ z_{15}(t-1]$$

$$(4.64)\quad z_{15}(t) = \rho_{15}\ [p_{15}(t),\ p_{14}(t),\ s_{15}(t-1),\ z_{15}(t-1)]$$

where (4.62) is the dynamic market equilibrium identity for soybean meal with $e_{15}(t)$ representing net exports. The demand for soybean meal is taken as exogenously determined since the specification of $q_{15}(t)$ in (4.62) is the only occurrence of the variable in the model. Relation (4.63) is the inventory-stock function for soybean meal with $E\ [p_{15}(t)]$ representing the futures price for soybean meal, and relation (4.64) is the production-flow function for soybean meal. A diagrammatic representation of the meal markets model is given in Figure 4.6.

For peanut meal, the initial theoretical specification is

$$(4.65)\quad q_{55}(t) = s_{55}(t-1) - s_{55}(t) + z_{55}(t) - e_{55}(t)$$

$$(4.66)\quad s_{55}(t) = \iota_{55}\ [p_{55}(t),\ p_{71}(t),\ s_{55}(t-1),\ z_{55}(t-1)]$$

$$(4.67)\quad z_{55}(t) = \rho_{55}\ [p_{55}(t),\ p_{54}(t),\ s_{55}(t-1),\ z_{55}(t-1)]$$

where (4.65) is the dynamic market equilibrium identity for peanut meal with $e_{55}(t)$ representing net exports. As in the case of soybean meal, the demand for peanut meal is taken as exogenously determined. Relation (4.66) is the inventory stock function for peanut meal and (4.67) is the production-flow function for peanut meal.

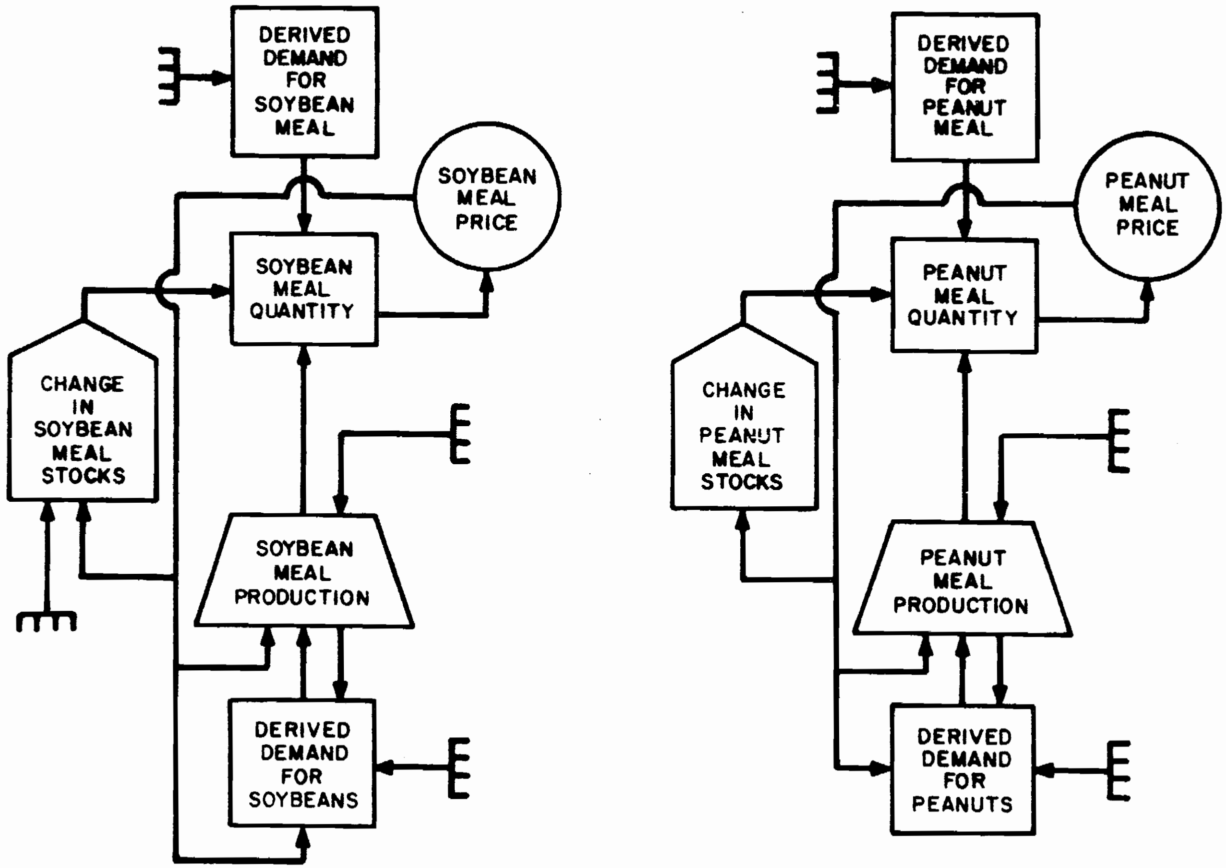

Figure 4.6. A Diagrammatic Representation of the Vegetable Meals Market Model

5. ESTIMATION OF THE PARAMETERS OF THE SYSTEM MODEL

A short discussion of the methods used to transform the theoretical model into empirical form, the reasons for using these methods, and the response to problems encountered in estimation is presented in this section. This topic is of much importance since the substantive conclusions of this study are conditioned to a considerable degree on the estimation techniques utilized. Section 5.1 provides an extended discussion of the model specification. Section 5.2 enumerates the particular problems of estimation encountered in this study. Section 5.3 discusses the techniques used for estimation and the reasons for the choices made.

5.1. The Model Specification

Section 4.2 provided a brief statement on the strategy used for the model specification. The remainder of Section 4 gave an explicit initial specification of the model used in this study. However, little was said about the length of the discrete time intervals of the variables in the model. The temporal aspects of the model are important, as will be demonstrated.

In many markets production and consumption decisions are made frequently by firms and consumers. For this reason the levels of market aggregates, particularly prices, may vary immensely over time periods as short as a month. This is especially true for commodity markets. Attempts to model volatile commodity markets using lengthy discrete time intervals for variable definitions are more likely to involve specification bias than the use of shorter discrete time intervals if the objective of analysis is to explain short-run behavior. For example, most traditional approaches for estimating the demands for food commodities use yearly data. This implies in the underlying model that consumers make a single consumption decision per year based on an average yearly price. Clearly a model which postulates a decision process like this to explain short-run behavior is unreasonable. Food consumption decisions are made often, usually weekly for most consumers. A yearly model abstracts temporally from actual decision processes. For this reason it is likely to be more difficult to specify. Shorter time interval models more closely approximate the actual frequency of decision-making and are less likely to be subject to specification bias. In this respect monthly models would be ranked above quarterly models, and quarterly models above yearly models in terms of susceptability to specification bias when actual market decisions are made frequently and the objective is to explain short-run behavior.

Besides reducing specification bias, three other reasons for developing monthly models of economic behavior have been suggested by Liu and Hwa [40]. First, government policy decisions are often made on the basis of the latest monthly data. A monthly model is necessary to determine what the impacts of such decisions will be. Second, short term forecasts are likely to be more accurate if made on the basis of a monthly model than on the basis of a quarterly or yearly model. For this reason monthly models can contribute to policy formulation in ways that quarterly and yearly models cannot. Agricultural economists have a tendency to think in terms of government policy impacts on a yearly basis because support prices are set for 12 month periods. However, policy impacts can be extremely significant over several months of a year and insignificant over the remainder. Third, monthly models involve less simultaneity in the system than quarterly or annual models. Over a year all prices and quantities ultimately influence each other. A drastic change in one sector in a monthly model may not have any effect on other sectors until several months have passed, however. For this reason, according to Liu and Hwa [40, p. 329], "estimation of monthly recursive relationships would suffer little in consistency and perhaps gain in efficiency."

The classical problem involved in the development of short-run models using monthly or quarterly data is that the disturbances of the estimated relations are likely to be autocorrelated. The result is unbiased OLS coefficients that are inefficient and asymptotically inconsistent, and biased estimated variances for the estimated coefficients. In this study Durbin-Watson d statistics and Durbin h statistics are used to analyze this objection. The results, which are presented in Appendix B, indicate the presence of some autocorrelation in the model. No corrective measures are taken, however, because of the complexity of dealing with autocorrelation in autoregressive simultaneous equation systems, and since the estimators are still unbiased.

As should be apparent from the discussion in Section 4, the method used to specify the model used in this study differs somewhat from the method normally used by econometricians in the specification of a large-scale simultaneous system. The usual procedure followed consists essentially of five stages, according to Duesenberry and Klein [16]. First, the endogenous variables to be predicted by the model are specified. Second, an equation explaining the determination of each endogenous variable is specified. Third, the variables entering each of these equations are then classified as endogenous, lagged endogenous, exogenous, or lagged exogenous. Fourth, additional equations are added to explain the newly introduced endogenous variables. And fifth, the process is repeated until all endogenous variables are explained.

Once the structure of traditional large-scale econometric models is specified, the model is refined by considering alternative functional forms and lag structures. These are tried out against the existing data base and any specification that does not describe the data with high R^2 values is immediately rejected, according to Christ [12]. Ratios of variables, combinations by division or multiplication--any device which generates high R^2's is utilized. Of course, this procedure requires a conviction for running and rerunning countless regressions with different combinations of variables until the R^2 values are driven virtually to unity. The end result may yield a satisfactory forecasting model (although the record of large-scale econometric models is questionable) but may not be meaningful to economists who believe in the existence of relatively stable structural economic functions. In this study the specification of the model is made on the basis of structure as opposed to only an interest in prediction, although considerable experimentation is utilized to select the specifications of the structural equations.

5.2. Other Problems of Estimation

There are several potential sources of bias in the estimated coefficients of the linear model developed in this study. First, only a limited number of the theoretically possible variables are included in the specification of the system. If a variable which should be included in the system model is omitted, then specification bias has been introduced. Second, linear demand, inventory-stock, production flow, and derived demand functions are assumed throughout the study. If the true market relationships are nonlinear, then the resulting linear estimates of the model are biased. Third, lagged endogenous variables are included throughout the model specification. The regression of endogenous variables on lagged endogenous variables results in biased or asymptotically biased parameter estimates, depending on the structural properties of the disturbance distributions.

Another potential problem is the possibility of a high degree of multicollinearity in some of the estimated relations. In the specification given in Section 4 virtually collinear substitute product prices were included in some finished product demand functions and, in many cases, highly collinear product and input prices were included in production-flow and derived demand relations. For this reason many of the OLS parameter estimates of the system are likely to be highly imprecise.

One additional problem of estimation involves the selection of the appropriate estimation technique for determining the parameters of the system. Generally, the best technique for the estimation of a simultaneous equation system is 3SLS or full-information maximum likelihood. If simultaneous equation bias is small, however, OLS or 3SLS applied to groups of equations in the system may be satisfactory. Under certain extreme cases OLS or subsystem 3SLS may even be superior to 3SLS. In this study OLS, subsystem 3SLS, and system 3SLS are all used to estimate the parameters of alternative specifications of the system model.

The reasons for evaluating multiple estimation techniques in the study are based on several factors. First, the OLS estimates are likely subject to simultaneous equation bias, given the specification of the model in Section 4. Also, the OLS estimates are likely biased because of the presence of lagged dependent variables in most of the relations. Second, the application of 3SLS to simultaneous subsystems of the model, while correcting for some simultaneous equation bias, is still subject to bias since lagged endogenous variables are included in the first and second stages of estimation. Third, the application of 3SLS to the entire simultaneous system is even more subject to bias from the inclusion of lagged endogenous variables in the model than for subsystem 3SLS since many more first and second stage regressions must be performed. In addition, 3SLS estimates of the entire system are more likely to be effected by ill-conditioning (round-off errors by the computer) than subsystem 3SLS or OLS. This problem has been considered by Freund [22], Ling [42], Longley [41], and Wampler [76].

Although ill-conditioning is a potential problem in OLS or in 3SLS estimates of subsystems, the problem is likely to be much worse in 3SLS estimates of the system since the three stage estimation procedure requires the sequential multiplication and inversion of many large matrices. This is the reason for using subsystem 3SLS--to avoid to some degree the possibility of ill-conditioning. Recent evidence provided by Boehm, Menkhaus, and Penn [5] is supportive of the 3SLS system estimates obtained in this study. Boehm, Menkhaus, and Penn use eight different programs to estimate two highly ill-conditioned test problems on four different computers. The results indicated that the Statistical Analysis System (SAS) and the Statistical Package for the Social Sciences (SPSS) performed the most satisfactorily of all the programs used. SAS and SPSS estimated all the test statistics accurately. The estimation program used in this study was SAS. For this reason, it follows that although ill-conditioning might still be possible, that possibility is minimized by the use of SAS in this study.

5.3. Estimation Procedure and Regression Strategy

A 4-stage procedure was utilized to specify and estimate the industry model. In the first stage the simultaneous equation model specified in Section 4 was estimated by OLS, subsystem 3SLS, and system 3SLS. The resulting model failed to satisfy the stability conditions for a linear system, however. In the second stage, the system was respecified by allowing lagged endogenous and exogenous variables to replace current endogenous and exogenous variables in the model. The appropriate length of lags for different variables and the equation specifications were selected by running many experimental regressions. The criteria for selection involved a subjective weighting of consistency of signs and magnitudes of the estimated parameters, the statistical significance of the estimates, and the explanatory power of the estimated relations.

In the third stage, the set of subjectively selected "best" equations was divided into groups of equations forming simultaneous systems. These systems were then estimated using simultaneous equation system estimation methods and each system was evaluated to determine whether stability conditions were satisfied. If the specified system failed to satisfy stability conditions further experimentation was undertaken by respecification and re-estimation until a stable or almost stable system was obtained. In the fourth stage, since the lagged structures of virtually all the simultaneous systems in the model were integrated, simultaneous equation systems were combined into single block-diagonal systems. The block-diagonal systems were then evaluated to determine whether stability conditions were satisfied. If the block-diagonal systems were unstable, then alternative combinations of blocks were evaluated for stability.

The ultimate objective of the model construction procedure was to obtain a stable block-diagonal system with an integrated lagged structure. The realization of this objective necessarily results in economies when the performance of the system is evaluated and when simulations are undertaken. However, the larger the size of any given matrix, the greater is the probability that one of the eigenvalues of the matrix will be greater than unity in absolute value. For this reason, it is more difficult to satisfy stability conditions the larger is the linear system under consideration. In this study the industry model could not be reduced to a single stable block-diagonal system. Instead 4 separate industry models resulted, each block-diagonal and stable (these results are discussed in Section 6).

Because of the possibilities of different types of bias or ill-conditioned estimation, it is not immediately apparent whether OLS, subsystem 3SLS, or system 3SLS is the appropriate estimation technique for estimating the simultaneous equation systems considered in this study. To select the "best" set of estimates for each system, each parameter set was first evaluated to determine whether it constituted a stable system. For example, if 3SLS estimates of a particular system were unstable and OLS estimates were stable, then the OLS estimates were selected as the appropriate estimates of the system. In cases where OLS, subsystem 3SLS, and 3SLS estimates generated stable systems, the "best" estimates of the system were selected on the basis of which set generated the lowest mean inequality coefficient for the equations of the system.

In general, the evaluation of multiple sets of estimators was desirable with respect to stability analysis since small perturbations in the elements of the matrix of estimated coefficients associated with the lagged endogenous variables of a system can have large effects on levels of the eigenvalues of the matrix. Hence a system very close to being stable (unstable) can become stable (unstable) as a consequence of slight perturbations in the estimated coefficients of the system resulting from re-estimation utilizing an alternative estimation technique.

6. RESULTS OF ESTIMATION

This section presents the empirical industry model constructed by following the specification and estimation procedure described in Section 5.3. The complete industry model includes 4 independent sub-models and contains most of the markets specified in Section 4. The first sub-model consists of 3 simultaneous equation blocks, includes 14 equations, and is composed of the finished product markets of the industry. The second sub-model is completely simultaneous, includes 17 equations, and is composed of the markets for finished soybean oil, semi-finished soybean oil, soybeans, and soybean meal. The third sub-model consists of 2 simultaneous equation blocks, includes 18 equations, and is composed of the markets for finished cottonseed oil, semi-finished cottonseed oil, semi-finished peanut oil, and peanuts. The fourth sub-model is completely simultaneous, consists of 10 equations, and is composed of the markets for semi-finished coconut and palm oil.

The estimated relations reported in this section are based on a 136 month data base covering the period January 1965 to April 1976. Data sources are discussed in Appendix C. In addition, references to Table 4.1 may be necessary in the reading of this section since, in some cases, variable symbols previously identified are not redefined. Section 6.1 presents the final empirical form of the finished products sub-model. Section 6.2 presents the final form of the soybean, soybean oil, and soybean meal sub-model. Section 6.3 presents the final form of the cottonseed oil, peanut oil, and peanut sub-model. Section 6.4 presents the final empirical form of the imported oils sub-model.

6.1. The Finished Products Sub-model

The basic structure of the finished products sub-model constructed for this study is described by the system

$$(6.1)\quad A_1y_t + A_2y_{t-1} + A_3x_t + A_4x_{t-1} = u_t,\ t = 1, \ldots, T,$$

where $A_1 = \begin{bmatrix} A_1^{(1)} & 0 & 0 \\ 0 & A_1^{(2)} & 0 \\ 0 & 0 & A_1^{(3)} \end{bmatrix} \qquad y_t = \begin{bmatrix} y_t^{(1)} \\ y_t^{(2)} \\ y_t^{(3)} \end{bmatrix}$

The $A_1^{(i)}$, $i = 1, \ldots, 3$, are matrices of estimated coefficients for each of three simultaneous equation systems with the $y_t^{(i)}$, $i = 1, \ldots, 3$, representing the corresponding vectors of endogenous variables for each system. The y_{t-1}, x_t, and x_{t-1} are vectors which represent the lagged endogenous, exogenous, and lagged exogenous variables of the complete system. The A_j, $j = 2, \ldots, 4$, represent the matrices of estimated coefficients corresponding to these vectors, respectively. These matrices are structurally integrated and not block-diagonal, as is A_1.

Because A_1 in relation (6.1) is block-diagonal, the structure of the finished products model can be described as consisting of a non-integrated endogenous component, with integrated lagged endogenous, exogenous, and lagged exogenous components. The blocks of a system of this type may be treated separately with respect to estimation, according to Kmenta [30], if the variance-covariance matrix is block-diagonal. Otherwise the blocks are "seemingly" unrelated. With respect to stability analysis, however, the complete system must be considered in the context of relation (6.1).

The first simultaneous block included in the A_1 matrix of relation (6.1) represents the cooking oil and shortening markets. This block consists of 8 equations--a final demand function, a dynamic supply identity, an inventory-stock function, and a production-flow function for each product--two basic simultaneous equation models of the type developed in Section 3. The cooking oil and shortening markets are linked simultaneously by the inclusion of cooking oil and shortening price in the demand functions for both of these products. The second simultaneous block in relation (6.1) represents the margarine market. This block consists of 4 equations--a final demand function, a dynamic supply identity, an inventory-stock function, and a production-flow function--a basic simultaneous equation model of the type developed in Section 3. The third simultaneous block included in the A_1 matrix of relation (6.1) represents the peanut butter market. This block consists of two equations--a demand and supply function. A 4-equation system could not be specified for this market because of data limitations.

A variety of alternative specifications were estimated to select the included variables and lag structure for each equation in the finished products model. The criteria for specification were discussed in Section 5. After many alternatives were tried, OLS estimates of the equations presented in the following paragraphs were selected as appropriate. Other estimation techniques generated estimated coefficients which formed mathematically unstable systems.

For the cooking oil market, the final form of the demand function was determined to be:

$$
\begin{aligned}
(6.2)\quad q_{11}(t) = {} & \underset{(11420)}{71662} - \underset{(16.39)}{15.30}\, p_{11}(t) + \underset{(5.871)}{1.578}\, p_{21}(t) + \underset{(6026)}{63246}\, y(t) \\
& - \underset{(.0866)}{.1151}\, q_{11}(t-1) + \underset{(7234)}{10564}\, d_1 + \underset{(6966)}{23512}\, d_3(t) + \underset{(7385)}{17911}\, d_5(t) \\
& + \underset{(7105)}{35675}\, d_6(t) + \underset{(7249)}{12593}\, d_7(t) + \underset{(7118)}{19362}\, d_8(t) + \underset{(7146)}{14681}\, d_{10}(t), \\
& R^2 = .8383.
\end{aligned}
$$

Standard errors of each estimated coefficient are presented in parentheses beneath each reported parameter and the variable symbols are defined as indicated in Table 4.1. The reported coefficients indicate that the prices of cooking oil and shortening, $p_{11}(t)$ and $p_{21}(t)$, are not statistically significant, where statistically significant is defined in this section arbitrarily to refer to a variable with a t statistic approximately greater than 2. This is likely a consequence of collinearity, however, since the correlation coefficient between these two time series is .9955. Of particular interest in this relation are the signs and magnitudes of the dummy variables representing monthly demand effects. Large positive monthly effects are indicated for May, June, July, and August. This result was expected prior to estimation because in the summer months the demand for mayonnaise and salad dressing increases. Since cooking oil used in mayonnaise and salad dressing is classified as cooking oil when it is processed, the demand for cooking oil in the summer months would be expected to increase. Regarding the elasticities associated with the coefficients presented in equation (6.2), the price elasticity of demand, the cross-price elasticity of shortening, and the income elasticity, evaluated at the mean levels of the sample, were found to be -.2671, .0659, and 1.0023, respectively.

From this it follows the monthly demand for cooking oil is highly inelastic, that shortening is an inelastic substitute for cooking oil on a monthly basis, and that cooking oil is a "superior" good, if the estimated parameters in relation (6.2) are accepted as nonzero.

The second equation describing the cooking oil market is the identity given as relation (4.1) in Section 4. The third equation describing the cooking oil market consists of the inventory-stock function for cooking oil given in Section 4, rewritten with price as the dependent variable. The final form of this relation was determined to be

$$(6.3)\quad p_{11}(t) = \underset{(45.13)}{-153.9} + \underset{(.0080)}{.9761}\ p_{11}(t-1) + \underset{(.0008094)}{.0003397}\ [(s_{11}(t) - s_{11}(t-1)] + \underset{(.0641)}{.4446}\ p_{71}(t),\ R^2 = .9928.$$

Note that the lagged price of cooking oil, $p_{11}(t-1)$, and the short-term interest rate, $p_{71}(t)$, have t statistics greater than 2, but the first-difference in inventory-stocks of cooking oil, $s_{11}(t) - s_{11}(t-1)$, does not. This first difference is included in the relation nevertheless since changes in stocks must have some impact on market price.

An interesting result of using price instead of the inventory-stock level as the dependent variable in relation (6.3) was that the price autoregression resulted in a much greater degree of explanatory power for the equation. This same result was obtained for most other markets in this study. For this reason, the remaining empirical forms of the inventory-stock function presented in this section are written with price as the dependent variable. In addition to increased explanatory power, experiments with alternative specifications of different market models indicated that, in general, stability conditions were much more likely to be satisfied when at least one relation with a high degree of explanatory power, like relation (6.3), was included in the model specification.

The fourth equation describing the cooking oil market is a production-flow function with final form

$$
\begin{aligned}
(6.4)\quad z_{11}(t) = {} & \underset{(18946)}{97538} + \underset{(4.155)}{3.258}\; p_{11}(t-1) - \underset{(6.145)}{.4762}\; p_{12}(t-1) \\
& + \underset{(11.27)}{30.91}\,[(p_{13}(t-1) - p_{23}(t-1)] + \underset{(8.495)}{2.374}\,[p_{13}(t-1) - p_{43}(t-1)] \\
& - \underset{(9.219)}{26.18}\,[p_{13}(t-1) - p_{53}(t-1)] + \underset{(.0711)}{.5898}\; z_{11}(t-1),\ R^2 = .7142.
\end{aligned}
$$

Lagged prices and price differences are utilized in this relation because the amount of cooking oil produced in t, $z_{11}(t)$, is actually dependent on prices in t-1 because of the lag in delivery of crude oils to the finished product plants. If the estimated parameters for p_{11} and p_{12} are actually nonzero (these 2 variables are virtually collinear), the signs of the estimated coefficients of this equation are consistent with expectations--an increase in the price of cooking oil in t-1 has a positive effect on production in t; similarly, an increase in the lagged price of soybean oil, $p_{12}(t-1)$, in t-1, has a negative effect on production in t.

For the shortening market the final form of the demand function was determined to be

$$
\begin{aligned}
(6.5)\quad q_{21}(t) = {} & \underset{(9848)}{86717} - \underset{(4.172)}{6.213}\; p_{21}(t) + \underset{(11.21)}{3.826}\; p_{11}(t) + \underset{(3.323)}{10.38}\, p_{41}(t) \\
& + \underset{(3876)}{31287}\; y(t) - \underset{(5141)}{8360}\; d_2(t) + \underset{(4886)}{3697}\; d_3(t) - \underset{(4935)}{17669}\, d_4(t)
\end{aligned}
$$

$$- \underset{(5048)}{19642}\ d_6(t) - \underset{(5255)}{12708}\ d_7(t) + \underset{(5239)}{2896}\ d_8(t) + \underset{(5123)}{2962}\ d_9(t)$$

$$+ \underset{(5160)}{22096}\ d_{10}(t) + \underset{(5634)}{7297}\ d_{11}(t) + \underset{(.0841)}{.0693}\ q_{21}(t-1),\ R^2 = .8179.$$

For this equation, as in the case of cooking oil, the estimated coefficients for shortening and cooking oil prices are not significant. Again, this result is likely to be a consequence of collinearity between the two series. Accepting the estimated coefficients as nonzero implies that the direct price elasticity, the cross-price elasticity, and the income elasticity for this relation are -.3432, .0883, and .6554, respectively. Hence, the demand for shortening is highly inelastic, cooking oil is an inelastic substitute for shortening, and shortening is a "necessity" good. The coefficients for the dummy variables for months in relation (6.6) indicate an important role for seasonal factors in the demand for shortening. In April, June, and July, represented by $d_4(t)$, $d_6(t)$, and $d_7(t)$, the demand for shortening is much less than during the rest of the year (as indicated by the negative magnitudes of the monthly dummy variables). This result is compatible with the finding that more cooking oil is demanded during this same period for use in salad dressing and mayonnaise--consumers substitute one form of vegetable oil product for another in the summer.

The final form of the inventory-stock function for the shortening market was determined to be

$$(6.6)\quad p_{21}(t) = \underset{(113.4)}{-466.9} + \underset{(.0081)}{.9745}\ p_{21}(t-1) + \underset{(.002880)}{.005168}\ [s_{21}(t) - s_{21}(t-1)]$$

$$+ \underset{(.1691)}{1.237}\ p_{71}(t-1),\ R^2 = .9929.$$

In this relation the variable representing change in stocks, $s_{21}(t) - s_{21}(t-1)$, is almost significant. This contrasts with the results for the inventory-stock function for the cooking oil market. Also the sign on the short-term interest rate is positive, as for the cooking oil market. The significant role of short-term interest rates is of interest since it is difficult to imagine processing firms in the industry adjusting prices rapidly in response to interest rate changes. However, short-term interest rates are highly correlated with the rate of inflation. For this reason, it is possible that $p_{71}(t)$ serves partially as an index of the inflation rate. As all other prices rise as a consequence of a general inflation, the price of shortening would also be expected to rise. For this reason, since the signs of the estimated coefficients for interest rates are positive for both cooking oil and shortening, it is quite likely that short-term interest rates are serving as a proxy for the inflation rate in the inventory stock functions considered in this section.

For the production-flow function of the shortening market, the final form was determined to be

$$
\begin{aligned}
(6.7)\quad z_{21}(t) = {} & \underset{(17938)}{108573} + \underset{(1.577)}{5.424}\ p_{21}(t-1) - \underset{(7.907)}{21.83}\ p_{12}(t-1) \\
& - \underset{(2.550)}{.5328}\ [p_{13}(t-1) - p_{33}(t-1)] + \underset{(7.331)}{23.22}\ [p_{13}(t-1) - p_{63}(t-1)] \\
& - \underset{(.1630)}{.5595}\ s_{21}(t-1) + \underset{(.0651)}{.6129}\ z_{21}(t-1),\ R^2 = .6987.
\end{aligned}
$$

The signs of the estimated coefficients for finished product prices in this relation are consistent with expectations--an increase in the price of shortening in t-1 leads to an increase in the production of shortening in t, everything else constant; an increase in the price of refined soybean oil, $p_{12}(t-1)$, in t-1 leads to a decrease in the production of shortening in t.

The second simultaneous equation block of the finished products sub-model consists of 4 equations describing the margarine market. The final form of the first equation in this block, the demand function for margarine, is

$$
\begin{aligned}
(6.8)\quad q_{31}(t) = \; & \underset{(15131)}{141171} - \underset{(1.509)}{8.264}\; p_{31}(t) + \underset{(1.742)}{7.776}\; p_{51}(t) + \underset{(2601)}{18261}\; y(t) \\
& - \underset{(.0866)}{.2632}\; q_{31}(t-1) + \underset{(4513)}{8321}\; d_1(t) - \underset{(4643)}{15059}\; d_2(t) - \underset{(4460)}{16762}\; d_3(t) \\
& - \underset{(4417)}{31346}\; d_4(t) - \underset{(4948)}{33458}\; d_5(t) - \underset{(4850)}{36595}\; d_6(t) - \underset{(4993)}{47829}\; d_7(t) \\
& - \underset{(5420)}{37145}\; d_8(t) - \underset{(4819)}{27468}\; d_9(t) - \underset{(4627)}{12526}\; d_{10}(t) - \underset{(4459)}{7842}\; d_{11}(t), \\
& R^2 = .8135.
\end{aligned}
$$

All of the estimated coefficients of this relation are significant (with t-statistics greater than 2) with the exception of the monthly dummies for January and November. The price elasticity of demand, the cross-price elasticity for butter, and the income elasticity are -.1617, .3694, and .4098, respectively. The signs of the monthly seasonal dummies indicate that the demand for margarine is greatest in the winter months and lowest in the summer. Again, this result is compatible with the assertion that the demand for mayonnaise and salad dressing substitutes for the demand for other oils in the summer.

The final form of the inventory-stock function for margarine was determined to be

$$(6.9)\quad p_{31}(t) = \underset{(30.70)}{-155.2} + \underset{(.0066)}{.9766}\ p_{31}(t-1) + \underset{(.001165)}{.002366}\ [s_{31}(t) - s_{31}(t-1)] + \underset{(.0453)}{.4011}\ p_{71}(t-1),\ R^2 = .9951,$$

and the final form of the production-flow function for margarine was determined to be

$$(6.10)\quad z_{31}(t) = \underset{(15600)}{105419} + \underset{(4.746)}{19.30}\ p_{31}(t-1) - \underset{(7.402)}{26.87}\ p_{12}(t-1) - \underset{(6.048)}{.6511}\ [p_{13}(t-1) - p_{43}(t-1)] - \underset{(2.326)}{.5503}\ [p_{13}(t-1) - p_{33}(t-1)] + \underset{(6.487)}{27.36}\ [p_{13}(t-1) - p_{63}(t-1)] - \underset{(.1811)}{.5835}\ s_{31}(t-1) + \underset{(.0924)}{.5001}\ z_{31}(t-1),\ R^2 = .5685.$$

All of the estimated coefficients of both of these relations are of the appropriate sign and most have t statistics greater than 2, except for the coefficients representing differences between the price of crude soybean oil and coconut oil, and crude soybean oil and palm oil prices.

The third simultaneous equation block of the finished products model consists of a demand and supply function describing the peanut butter market. The final form of the demand function for peanut butter was determined to be

$$(6.11)\quad q_{91} = \underset{(4893)}{14773} - \underset{(1.330)}{1.250}\ p_{91}(t) + \underset{(.8950)}{1.122}\ p_{31}(t-1) + \underset{(858.6)}{3155}\ y(t-1) + \underset{(.0857)}{.3567}\ q_{91}(t-1) + \underset{(1452)}{11267}\ d_1(t) + \underset{(1470)}{6942}\ d_2(t) + \underset{(1422)}{7291}\ d_3(t) + \underset{(1424)}{5081}\ d_4(t) + \underset{(1417)}{6158}\ d_5(t) + \underset{(1420)}{4469}\ d_6(t) + \underset{(1404)}{2141}\ d_7(t)$$

$$+ \underset{(1412)}{11098}\ d_8(t) + \underset{(1493)}{9266}\ d_9(t) + \underset{(1518)}{10913}\ d_{10}(t) + \underset{(1595)}{1256}\ d_{11}(t),$$

$$R^2 = .8006.$$

The price elasticity of demand and the income elasticity for peanut butter are -.1841 and .2852. The signs and magnitudes of the monthly dummies indicate that the demand for peanut butter is greatest in August, September, October, and January.

For peanut butter, the final form of the supply equation was determined to be

$$(6.12)\quad p_{91}(t) = \underset{(250.2)}{3031} + \underset{(.004950)}{.008983}\ q_{91}(t) - \underset{(.1710)}{.7653}\ p_{71}(t-1) + \underset{(.1169)}{1.1856}$$

$$p_{54}(t-2) + \underset{(.0486)}{.5521}\ p_{53}(t-2),\ R^2 = .9322.$$

Note that the variables included in this relation are a spurious combination of those variables included in the dynamic supply identity, the inventory-stock function, and the production-flow function from the general 4-equation simultaneous market system developed in Section 3. The signs of shelled peanut price and the price of crude peanut oil, represented by p_{54} and p_{53}, are consistent with expectations. As the price of either of these two inputs increases, the price of peanut butter increases. The estimated coefficient for short-term interest rates is negative, however. This result contrasts with previous findings for cooking oil, shortening, and margarine. Also, the price elasticity of supply for peanut butter, evaluated at the mean sample level, is 16.3890, indicating a very elastic supply on a monthly basis.

In summary, all of the signs of the estimated coefficients of the finished products model are consistent with general expectations. In addition, most of these coefficients have associated t statistics greater than 2. Some important price variables are statistically insignificant, however. The monthly demand elasticities for cooking oil, shortening, margarine, and peanut butter are all highly inelastic. The income elasticities are all positive and less than unity, with the exception of the income elasticity for cooking oil, which is slightly greater than unity. Of course, the levels of structural elasticities in simultaneous equation systems are somewhat ambigous since when price and quantity are endogenous, only changes in lagged endogenous, exogenous, and lagged exogenous variables can effect their levels. Nevertheless, structural elasticities are useful for evaluating the consistency of estimated parameters and have been reported here for this purpose.

6.2. The Soybean, Soybean Oil, and Soybean Meal Sub-model

The soybean, soybean oil, and soybean meal sub-model consists of 17 simultaneous equations and is composed essentially of 4 basic commodity models of the type developed in Section 3. The 4 included markets are the market for soybeans, semi-finished soybean oil, finished soybean oil, and soybean meal. The specification of the markets for these products is the same as that presented in Section 4, except that various endogenous variables in the previous specification are now classified as lagged endogenous variables. The replacement of endogenous with lagged endogenous variables has the effect of transforming the soybean, semi-finished soybean oil, finished soybean oil, and soybean meal markets into a simultaneous system independent of the other markets discussed in Section 4. The estimates of this system, as reported in this section, are 3SLS estimates (OLS estimates resulted in an unstable system).

For the finished soybean oil market, the final form of the derived demand functions for finished soybean oil used in cooking oil, shortening, and margarine take the form

$$(6.13)\quad q_{12}^{(1)}(t) = \underset{(14049)}{44017} - \underset{(2.288)}{.6741}\, p_{12}(t-1) + \underset{(3578)}{15488}\, y(t-1) + \underset{(5.521)}{6.182}$$
$$[p_{13}(t-1) - p_{23}(t-1)] + \underset{(4.125)}{.4898}\, [p_{13}(t-1) - p_{43}(t-1)] - \underset{(4.573)}{1.284}$$
$$[p_{13}(t-1) - p_{53}(t-1)] - \underset{(.1089)}{.3096}\, z_{11}(t-1) + \underset{(.0572)}{.1585}\, s_{11}(t-1)$$
$$+ \underset{(.1204)}{.8522}\, q_{12}^{(1)}(t-1),\ R^2 = .8760,$$

$$(6.14)\quad q_{12}^{(2)}(t) = \underset{(9298)}{112997} - \underset{(2.142)}{9.724}\, p_{12}(t-1) + \underset{(1877)}{14802}\, y(t-1) - \underset{(1.261)}{3.084}$$
$$[p_{13}(t-1) - p_{33}(t-1)] + \underset{(2.638)}{8.957}\, [p_{13}(t-1) - p_{63}(t-1)] - \underset{(.0741)}{.1435}$$
$$z_{21}(t-1) - \underset{(.0771)}{.4595}\, s_{21}(t-1) + \underset{(.0855)}{.4785}\, q_{12}^{(2)}(t-1),\ R^2 = .7464,$$

$$(6.15)\quad q_{12}^{(3)}(t) = \underset{(7489)}{59994} - \underset{(1.6061)}{.3703}\, p_{12}(t-1) + \underset{(1770)}{5466}\, y(t-1) - \underset{(2.806)}{3.916}\, [p_{13}(t-1)$$
$$- p_{43}(t-1)] + \underset{(1.047)}{2.250}\, [p_{13}(t-1) - p_{33}(t-1)] + \underset{(2.278)}{2.382}\, [p_{13}(t-1)$$
$$- p_{63}(t-1)] - \underset{(.1116)}{.1108}\, z_{31}(t-1) - \underset{(.0916)}{.3589}\, s_{31}(t-1) + \underset{(.1638)}{.6466}\, q_{12}^{(3)}(t-1),$$
$$R^2 = .6944,$$

where the reported R^2 are those of the corresponding OLS regressions. Note that lagged income variables have been added to each derived demand function since the soybean, soybean oil, and soybean meal submodel is no longer simultaneous with the finished product markets. In addition, all variables on the right-hand side of each derived demand function have been lagged one month. This has been done to reflect the fact that finished product manufacturers place orders for finished or semi-finished soybean oil in month t, based on prices in t. However, storage and delivery time before utilization usually require one month. For this reason, the quantity of soybean oil used in finished products in t is actually demanded or ordered in t-1.

An examination of relations (6.13), (6.14), and (6.15) will indicate that several of the estimated coefficients are not statistically significant, including the price of finished soybean oil in relations (6.13) and (6.15). These variables are retained in the equations, however, because they are theoretically appropriate. The estimated coefficients for the price of finished soybean oil are all negative, as expected, and the estimated coefficients for income are positive. The associated price elasticities of demand for each relation (using lagged prices) are -.0056, -.1004, and -.0055, respectively, while the corresponding income elasticities are .3164, .3728, and .1984, respectively. The signs on the price differences between semi-finished soybean oil, $p_{13}(t-1)$, and substitute oils differ--some are positive, others negative. It would seem logical to expect that as the price spread between soybean oil and substitute oils increases, less soybean oil would be demanded. However, this is not a sufficiency condition of the market model developed in Section 3. In fact, most producers will substitute other oils for soybean oil only up to a level consistent with their product standards. Hence, the price spread could increase and more soybean oil would be utilized beyond a certain saturation point. For this reason, some of the signs on price spreads in relations (6.13), (6.14), and (6.15) could be positive.

The fourth relation describing the finished soybean oil market is identity (4.33) given in Section 4. The fifth relation describing the finished soybean oil market is an inventory-stock function with final form

$$(6.16)\quad p_{12}(t) = \underset{(23.92)}{209.8} + \underset{(.0222)}{.1113}\, p_{12}(t-1) + \underset{(.0236)}{.9134}\, p_{13}(t) - \underset{(.0419)}{.1049}\, p_{71}(t-1)$$

$$+ \underset{(.0004578)}{.001332}\, [s_{12}(t) - s_{12}(t-1)],\ R^2 = .9910.$$

The sixth relation describing the finished soybean oil market is a production-flow function with final form

$$(6.17)\quad z_{12}(t) = \underset{(20145)}{138741} + \underset{(23.07)}{76.17}\, p_{12}(t) - \underset{(22.58)}{64.73}\, p_{13}(t) + \underset{(.0429)}{.6563}\, z_{12}(t-1),$$

$$R^2 = .7056.$$

For both of these functions all estimated coefficients have t statistics greater than 2 in value and there are no inconsistencies between expected and estimated signs, with the exception of the coefficient on short-term interest rates in relation (6.16).

The semi-finished soybean oil market consists of a derived demand function, an inventory-stock function, a production-flow function, and identity (4.41) in Section 4. The final form of the derived demand function for semi-finished soybean oil is

$$(6.18)\quad q_{13}(t) = \underset{(29298)}{92937} + \underset{(6835)}{55934}\, y(t-1) - \underset{(5.969)}{13.81}\, p_{13}(t-1) - \underset{(.0802)}{.2360}\, s_{12}(t-1)$$

$$+ \underset{(.1126)}{.7685}\, z_{12}(t-1) - \underset{(.0798)}{.2395}\, q_{13}(t-1),\ R^2 = .7333.$$

For this relation, all t-statistics are greater than 2 and the signs of the estimated coefficients are consistent with expectations. The price elasticity of demand and the income elasticity are -.0419 and .4680, respectively.

For the inventory-stock and production-flow functions of the semi-finished soybean oil market, the final forms are

$$(6.19)\quad p_{13}(t) = \underset{(24.81)}{-252.3} - \underset{(.0293)}{.0493}\, p_{13}(t-1) + \underset{(.0365)}{.9422}\, p_{12}(t) + \underset{(.0565)}{.0662}\, p_{14}(t)$$

$$+ \underset{(.0440)}{.1315}\, p_{71}(t-1) + \underset{(.0310)}{.0849}\, E[p_{13}(t)] - \underset{(.0001434)}{.0006659}\, [s_{13}(t) - s_{13}(t-1)],$$

$$R^2 = .9909.$$

and

$$(6.20)\quad z_{13}(t) = \underset{(23199)}{151702} + \underset{(10.22)}{33.17}\, p_{13}(t-1) - \underset{(84.81)}{162.9}\, p_{14}(t-1) + \underset{(1.944)}{2.242}$$

$$p_{15}(t-1) + \underset{(.0385)}{.7353}\, z_{13}(t-1),\ R^2 = .7497.$$

Most of the coefficients of these 2 relations have t statistics greater than 2, and all estimated signs are consistent with expectations, with the exception of the negative coefficient on change in stocks in relation (6.19). The futures price of semi-finished soybean oil is included in relation (6.19) to represent price expectations as discussed in Section 3. This variable captures the effects of current market information on futures prices and hence is directly related to current price.

A derived demand function, identity (4.58), and an inventory-stock function are used to describe the soybean market. The final form of the derived demand for processed soybeans is

$$
\begin{aligned}
(6.21)\quad q_{14}(t) = {} & \underset{(1773)}{12369} - \underset{(4.120)}{11.07}\, p_{14}(t-1) + \underset{(.6835)}{1.296}\, p_{13}(t-2) \\
& - \underset{(.0939)}{.0014}\, p_{15}(t-2) + \underset{(518.8)}{3938}\, y(t-1) - \underset{(.002296)}{.006235}\, s_{13}(t-1) \\
& - \underset{(.4585)}{1.000}\, s_{15}(t-1) + \underset{(.0400)}{.6162}\, q_{14}(t-1),\ R^2 = .8406.
\end{aligned}
$$

Note that all estimated signs are consistent with expectations, with the exception of the negative coefficient on the price of soybean meal (however, this coefficient has a t statistic less than 2 in value). The elasticity of demand for processed soybeans, evaluated with respect to $p_{14}(t-1)$ at the mean sample level, is -.0767.

The inventory-stock function for the soybean market has final form

$$
\begin{aligned}
(6.22)\quad p_{14}(t) = {} & \underset{(4.401)}{13.36} + \underset{(.0291)}{.1618}\, p_{14}(t-1) + \underset{(.0065)}{.0502}\, p_{13}(t) \\
& + \underset{(.0003691)}{.003451}\, E[p_{14}(t)] + \underset{(.00104)}{.01014}\, p_{15}(t) - \underset{(4.922)}{6.492}\, d_7(t) \\
& + \underset{(5.215)}{6.203}\, d_8(t) - \underset{(5.149)}{10.44}\, d_9(t) - \underset{(.006184)}{.002736}\, p_{44}(t) \\
& - \underset{(.00005957)}{.0001647}\, [s_{14}(t) - s_{14}(t-1)],\ R^2 = .9895.
\end{aligned}
$$

As for the semi-finished soybean oil inventory-stock function, the futures price of soybeans enters this relation to represent price expectations at a highly significant level. Also of interest is the negative sign on the dummy variable representing September--the arrival of harvest time is sufficient to cause a decline in price.

The final market considered in the soybean, soybean oil, and soybean meal sub-model is the market for soybean meal. The final form of the derived demand function for soybean meal is

$$(6.23)\quad q_{15}(t) = \underset{(472.8)}{5067} - \underset{(.0169)}{.0893}\, p_{15}(t-1) + \underset{(172.7)}{1202}\, y(t-1) - \underset{(.2035)}{.4511}\, p_{44}(t-1)$$
$$+ \underset{(.0617)}{.1705}\, q_{15}(t-1) - \underset{(236.2)}{532.5}\, d_9(t),\ R^2 = .6391.$$

Although the explanatory power of this relation is quite low, all of the included variables have t statistics greater than 2 in value. The price elasticity of demand, evaluated with respect to $p_{15}(t-1)$, and the income elasticity are -.0930 and .4957, respectively. All estimated signs are consistent with expectations except that the negative sign estimated for corn price, $p_{44}(t-1)$, is negative. Corn is generally regarded as a substitute for soybean meal, but may be complementary over certain price ranges.

The second and third relations describing the soybean meal market are identity (4.62) and an inventory-stock function. The final form of the inventory-stock function for soybean meal is

$$(6.24)\quad p_{15}(t) = \underset{(521.2)}{-720.9} + \underset{(.0377)}{.3612}\, p_{15}(t-1) + \underset{(1.695)}{30.96}\, p_{14}(t) - \underset{(.2744)}{4.214}\, p_{44}(t)$$
$$- \underset{(.3427)}{.4230}\, [s_{14}(t) - s_{14}(t-1)] + \underset{(.0421)}{.1519}\, z_{15}(t-1),\ R^2 = .9489.$$

The fourth relation describing the soybean meal market is a production-flow function with final form

$$(6.25)\quad z_{15}(t) = \underset{(516.8)}{3246} - \underset{(.0211)}{.0520}\, p_{15}(t-1) + \underset{(.7157)}{1.120}\, p_{14}(t-2) + \underset{(.1481)}{.2890}$$

$$p_{13}(t-1) - \underset{(.0665)}{.0127}\, s_{15}(t-1) + \underset{(.0391)}{.7384}\, z_{15}(t-1),\ R^2 = .7534.$$

For relation (6.25) the estimated coefficient for the lagged price of soybean meal is negative. This result is somewhat perverse since the implication is that an increase in the price of soybean meal in t-1 leads to a decrease in the production of soybean meal in t. In addition, the estimated coefficient for the price of soybeans lagged 2 quarters is positive. Again, this result is unusual since an increase in the price of soybeans would be expected to have a negative impact on soybean meal production.

In summary, most of the signs of the estimated coefficients of the soybean, soybean oil, and soybean meal sub-model are consistent with expectations and most of the associated t statistics are greater than 2 in value. The monthly demand elasticities of finished soybean oil used in cooking oil, finished soybean oil used in shortening, finished soybean oil used in margarine, semi-finished soybean oil, soybeans, and soybean meal, are all inelastic (and of the appropriate sign). The explanatory power of some of the relations in the soybean, soybean oil, and soybean meal sub-model is not as great as that of most of the relations of the finished products sub-model, however. This may not be a consequence of specification, but of the quality of the data base.

6.3. The Cottonseed Oil, Peanut Oil, and Peanut Sub-model

The structural form of the cottonseed oil, peanut oil, and peanut sub-model is identical to that of the finished products market except that there are 2 simultaneous equation blocks in the A_1 matrix instead of 3. The first simultaneous equation block includes the markets for finished and semi-finished cottonseed oil, and consists of 9 equations. The second simultaneous equation block includes the markets for semi-finished peanut oil and processed peanuts, and consists of 9 equations. All estimates reported in this section are 3SLS.

In the first simultaneous equation block the market for finished cottonseed oil is represented by 6 equations. These are the derived demand function for finished cottonseed oil used in cooking oil, the derived demand function for finished cottonseed oil used in shortening, the derived demand function for finished cottonseed oil used in margarine, identity (4.37), an inventory-stock function for finished cottonseed oil, and a production-flow function. The final form of the derived demand function for finished cottonseed oil used in cooking oil is

$$
\begin{aligned}
(6.26)\quad q_{22}^{(1)} = {} & \underset{(5593)}{50089} - \underset{(6.457)}{27.95}\, p_{22}(t-1) - \underset{(.9986)}{3.366}\, p_{11}(t-1) + \underset{(6.756)}{31.67}\, p_{12}(t-1) \\
& + \underset{(5.522)}{18.81}\, [p_{23}(t-1) - p_{13}(t-1)] - \underset{(2.076)}{6.631}\, [p_{23}(t-1) - p_{53}(t-1)] \\
& - \underset{(.0168)}{.0528}\, z_{11}(t-1) + \underset{(.0269)}{.0332}\, s_{11}(t-1) + \underset{(.0524)}{.4579}\, q_{22}(t-1) + \underset{(1701)}{6373}\, d_6(t) \\
& - \underset{(1722)}{4845}\, d_7(t)\ , \quad R^2 = .7798.
\end{aligned}
$$

Note that income has been omitted from this relation as a consequence of the specification process, as it has from the other 2 derived demand functions for finished cottonseed oil. Regarding the signs of the estimated coefficients of relation (6.26), the negative sign on cooking oil price is inconsistent with expectations. Most important, however, is the implied price elasticity of demand. For finished cottonseed oil this elasticity is -1.239 (evaluated at the mean sample level with respect to lagged price). This is in direct contrast to the inelastic derived demands obtained for finished soybean oil used in finished products, and is indicative of the role of cottonseed oil in the industry. When the price of cottonseed oil declines relative to the price of other oils, it is utilized in finished products to a much greater extent than other oils. The reason for this is economics, and the fact that cottonseed oil is a superior oil in quality--it can be substituted for virtually any oil. The converse is not true, however.

The final form of the derived demand functions for finished cottonseed oil used in shortening and margarine are

$$
\begin{aligned}
(6.27)\quad q_{22}^{(2)}(t) = {} & \underset{(2886)}{18747} - \underset{(1.667)}{5.479}\, p_{22}(t-1) + \underset{(.2097)}{.2923}\, p_{21}(t-1) \\
& + \underset{(1.269)}{3.5915}\, p_{12}(t-1) - \underset{(.3623)}{.7560}\, [p_{23}(t-1) - p_{33}(t-1)] \\
& + \underset{(.8708)}{1.280}\, [p_{23}(t-1) - p_{63}(t-1)] - \underset{(.008179)}{.03089}\, z_{21}(t-1) \\
& - \underset{(.02342)}{.06204}\, s_{21}(t-1) + \underset{(.03465)}{.7547}\, q_{22}^{(2)}(t-1) - \underset{(793.6)}{1592}\, d_7(t),\ R^2 = .8832,
\end{aligned}
$$

and

$$\text{(6.28)}\quad q_{22}^{(3)}(t) = \underset{(840.3)}{6135} - \underset{(.4126)}{.8439}\, p_{22}(t-1) + \underset{(.3954)}{.7080}\, p_{12}(t-1) +$$

$$+ \underset{(.04787)}{.6492}\, q_{22}^{(3)}(t-1) - \underset{(.009661)}{.01820}\, s_{31}(t-1) - \underset{(.004122)}{.01371}\, z_{31}(t-1)$$

$$+ \underset{(291.5)}{876.7}\, d_1(t) + \underset{(302.7)}{472.0}\, d_2(t) + \underset{(264.1)}{1040}\, d_{10}(t),\ R^2 = .7850.$$

Most of the estimated coefficients of these 2 relations have t-statistics greater than 2, and there are no inconsistencies between expected and reported signs. The price elasticities of demand for these relations are -.5665 and -.2926, respectively, indicating inelastic monthly demands for finished cottonseed oil used in shortening and margarine. However, most finished cottonseed oil is used in cooking oil (more than 46 percent of total usage), and by horizontally summing each derived demand function for finished cottonseed oil, the total derived demand for finished cottonseed oil may be derived. Because of the large amount of finished cottonseed oil used in cooking oil, the elasticity of this total demand function is -.9661. The corresponding total derived demand elasticity for soybean oil is -.0003. Hence the total derived demand for cottonseed oil is much more elastic than that of soybean oil.

The final forms of the inventory stock function for finished cottonseed oil is

$$\text{(6.29)}\quad p_{22}(t) = \underset{(23.88)}{247.3} + \underset{(.04326)}{.2039}\, p_{22}(t-1) + \underset{(.000263)}{.0003507}\, [s_{22}(t) - s_{22}(t-1)]$$

$$+ \underset{(.0320)}{.9492}\, p_{23}(t) - \underset{(.03540)}{.1232}\, p_{12}(t-1)\ ,\ R^2 = .9880.$$

The final form of the production-flow function for finished cottonseed oil is

$$\text{(6.30)}\quad z_{22}(t) = \underset{(8253)}{31791} - \underset{(10.87)}{8.916}\, p_{22}(t-2) + \underset{(10.83)}{8.937}\, p_{23}(t-2)$$

$$- \underset{(.0160)}{.0488}\, s_{22}(t-1) + \underset{(.06614)}{.5825}\, z_{22}(t-1) + \underset{(.05847)}{.2582}\, q_{23}(t-1),\ R^2 = .7011.$$

There are no inconsistencies between the expected and actual signs of the estimated coefficients in relation (6.29). For relation (6.30), the signs of the estimated coefficient for the price of finished cottonseed oil (lagged 2 months) and the price of semi-finished cottonseed oil (lagged 2 months), are reversed with respect to expectations. Since semi-finished cottonseed oil is the input, the coefficient on its price should be negative.

A derived demand function, identity (4.45), and an inventory-stock function are used to describe the market for semi-finished cottonseed oil. All attempts to estimate a production-flow function for this market lead to an unstable system, so for this reason no production-flow function is included in the specification of the semi-finished cottonseed oil market. The final form of the derived demand function for semi-finished cottonseed oil was determined to be

$$\text{(6.31)}\quad q_{23}(t) = \underset{(13617)}{112278} - \underset{(16.38)}{45.78}\, p_{23}(t-1) + \underset{(17.16)}{36.89}\, p_{22}(t-1)$$

$$+ \underset{(1.700)}{4.973}\, p_{24}(t-1) - \underset{(3572)}{24289}\, y(t-1) - \underset{(.02235)}{.1328}\, s_{22}(t-1)$$

$$+ \underset{(.08774)}{.3835}\, z_{22}(t-1) + \underset{(.08046)}{.3175}\, q_{23}(t-1),\ R^2 = .6602.$$

All estimated signs for this relation are appropriate, except perhaps for the negative sign on the income coefficient. The price elasticity of demand and the income elasticity are -.9431 and -1.2043, respectively. The negative income elasticity for semi-finished cottonseed oil is likely a consequence of the decline in cotton production over the last decade. Since income has increased over this period, an inverse relationship would be expected.

The final form of the inventory-stock function for semi-finished cottonseed oil is

$$(6.32)\quad p_{23}(t) = \underset{(25.97)}{-230.9} - \underset{(.02937)}{.004993}\, p_{23}(t-1) + \underset{(.03890)}{.8367}\, p_{22}(t)$$
$$- \underset{(.0003809)}{.0001292}\, [s_{23}(t) - s_{23}(t-1)] + \underset{(.0306)}{.1375}\, p_{13}(t),\ R^2 = .9873.$$

The t-statistic for lagged price of semi-finished cottonseed oil, $p_{23}(t-1)$, and for the change in stocks of semi-finished cottonseed oil, is small, although the explanatory power of the relation is large. This may be a result of collinearity among the price series since they are all highly correlated.

The second simultaneous equation block in the cottonseed oil, peanut oil, and peanut sub-model consists of 9 equations and includes the markets for semi-finished peanut oil and processed peanuts. The semi-finished peanut oil market is represented by 6 relations. These include a derived demand function for semi-finished peanut oil used in cooking oil, a derived demand function for peanut oil used in shortening, a derived demand function for semi-finished peanut oil used in margarine, identity (4.52), an inventory-stock function, and a production-flow function for semi-finished peanut oil. The final forms of the derived demand functions for semi-finished peanut oil used in cooking oil, shortening, and margarine are

$$(6.33)\quad q_{53}^{(1)} = \underset{(921.3)}{921.1} - \underset{(.2250)}{.6485}\, p_{53}(t-1) + \underset{(316.6)}{727.0}\, y(t-1)$$

$$+ \underset{(.5294)}{.7896}\,[p_{53}(t-1) - p_{13}(t-1)] - \underset{(.6518)}{.9351}\,[p_{53}(t-1) - p_{23}(t-1)]$$

$$- \underset{(.005330)}{.0009361}\, z_{11}(t-1) + \underset{(.0529)}{.7579}\, q_{53}^{(1)}(t-1) + \underset{(390.1)}{988.8}\, d_1(t)$$

$$- \underset{(421.8)}{905.3}\, d_7(t) + \underset{(392.2)}{1831}\, d_8(t),\ R^2 = .7974,$$

$$(6.34)\quad q_{53}^{(2)}(t) = \underset{(305.9)}{-170.2} - \underset{(.0778)}{.1748}\, p_{53}(t-1) + \underset{(118.3)}{191.8}\, y(t-1)$$

$$- \underset{(.0778)}{.1748}\,[p_{53}(t-1) - p_{33}(t-1)] + \underset{(.1512)}{.2728}\,[p_{53}(t-1) - p_{13}(t-1)]$$

$$- \underset{(.002298)}{.0002818}\, z_{21}(t-1) + \underset{(.0641)}{.6258}\, q_{53}^{(2)}(t-1) + \underset{(146.0)}{285.1}\, d_1(t)$$

$$+ \underset{(146.2)}{334.4}\, d_3(t) + \underset{(161.2)}{364.5}\, d_8(t) + \underset{(152.2)}{254.5}\, d_9(t),\ R^2 = .5382,$$

and

$$(6.35)\quad q_{53}^{(3)}(t) = \underset{(509.5)}{-1393} - \underset{(.1561)}{.5516}\, p_{53}(t-1) + \underset{(.1081)}{.3946}\, p_{31}(t-1)$$

$$+ \underset{(.1652)}{.1588}\,[p_{53}(t-1) - p_{13}(t-1)] - \underset{(.1627)}{.3828}\,[p_{53}(t-1) - p_{43}(t-1)]$$

$$+ \underset{(.1566)}{.4450}\,[p_{53}(t-1) - p_{63}(t-1)] + \underset{(.002791)}{.008056}\, z_{31}(t-1)$$

$$- \underset{(.004971)}{.01357}\, s_{31}(t-1) + \underset{(.0464)}{.8592}\, q_{53}^{(3)}(t-1) + \underset{(136.9)}{245.9}\, d_3(t)$$

$$+ \underset{(153.0}{421.2}\, d_5(t) + \underset{(153.3)}{395.5}\, d_6(t) + \underset{(154.0)}{380.5}\, d_7(t) + \underset{(169.1)}{583.0}\, d_8(t)$$

$$+ \underset{(152.7)}{304.4}\, d_9(t),\ R^2 = .7816.$$

For these relations there are no inconsistencies between expected and estimated signs. The explanatory power of these relations is not great, however, especially that of relation (6.34). The price elasticities of derived demand for the 3 relations are -.1573, -.0697, and -2.1581, respectively, indicating that the demand for semi-finished peanut oil used in margarine is very elastic, while the demands for semi-finished peanut oil used in cooking oil and shortening is inelastic. The total price elasticity of derived demand for semi-finished peanut oil, obtained by horizontal summation, is -.1073.

For semi-finished peanut oil, the final form of the inventory-stock function is

$$(6.36)\quad p_{53}(t) = \underset{(29.22)}{18.91} + \underset{(.03188)}{.7831}\, p_{53}(t-1) + \underset{(.003646)}{.002503}\, [s_{53}(t) - s_{53}(t-1)]$$

$$- \underset{(.00009674)}{.0003729}\, g_{54}(t) + \underset{(.0411)}{.2898}\, p_{13}(t),\ R^2 = .9788.$$

Note that the change in government stocks of peanuts, $g_{54}(t)$, has been included in this function as a determinant of price. The estimated coefficient for this variable is negative and highly significant. Conversely, the estimated coefficient for change in private stocks of peanut oil is positive, but not statistically significant. Both of these signs are consistent with expectations. Since $g_{54}(t)$ is defined as government stocks in t-1 minus government stocks in t, increases in both private and government stocks have positive effects on price.

The final form of the production-flow function for semi-finished peanut oil is

$$(6.37)\quad z_{53}(t) = \underset{(1837)}{-99.28} - \underset{(.4428)}{.1243}\, p_{53}(t-2) + \underset{(1.089)}{1.267}\, p_{54}(t-2)$$

$$- \underset{(.01804)}{.04573}\, s_{53}(t-1) + \underset{(.04805)}{.9495}\, z_{53}(t-1),\ R^2 = .7561.$$

For this relation, as for the production-flow function for finished cottonseed oil, the estimated coefficients on product price and input price are reversed and insignificant. Even if $p_{54}(t-2)$ is not taken as a proxy for peanut price (as is intended), a negative sign would still be expected on this variable. For this reason, there may be some problem with the specification of this relation.

Regarding the market for processed peanuts, 3 relations are included in the sub-model to describe this market. These are a derived demand function for processed peanuts, identity (4.60), and an inventory-stock function for peanuts. The final form of the derived demand function for processed peanuts is

$$(6.38)\quad q_{54}(t) = \underset{(5036)}{3831} - \underset{(3.403)}{3.954}\, p_{54}(t) - \underset{(1.321)}{1.595}\, p_{53}(t-2) - \underset{(.1081)}{.1114}\, p_{15}(t-2)$$

$$+ \underset{(1328)}{5400}\, y(t) + \underset{(.04089)}{.8169}\, q_{54}(t-1) + \underset{(1692)}{3620}\, d_3(t) - \underset{(1777)}{3939}\, d_6(t)$$

$$- \underset{(1790)}{6273}\, d_7(t) - \underset{(1838)}{6794}\, d_8(t) - \underset{(1924)}{5593}\, d_9(t),\ R^2 = .8361.$$

For this relation the sign on the price of semi-finished peanut oil is inconsistent with expectations, the price of soybean meal is included as a proxy for the price of peanut meal, and the seasonal dummies indicate that the demand for processed peanuts is lowest in the summer months. The price elasticity of derived demand and the income elasticity are -.1555 and .3843, respectively.

The final form of the inventory stock function for peanuts is

$$(6.39)\quad p_{54}(t) = \underset{(53.13)}{245.0} + \underset{(.0315)}{.8637}\, p_{54}(t-1) + \underset{(.00007589)}{.0002655}\, [s_{54}(t) - s_{54}(t-1)]$$

$$- \underset{(.0001037)}{.003447}\, g_{54}(t) - \underset{(29.48)}{75.37}\, d_1(t) - \underset{(30.95)}{123.0}\, d_8(t) - \underset{(65.30)}{314.1}\, d_9(t)$$

$$- \underset{(49.72)}{179.8}\, d_{10}(t) + \underset{(.0719)}{.1220}\, p_{14}(t-1) + \underset{(.01429)}{.0414}\, p_{53}(t),\ R^2 = .9568.$$

For this relation the signs on the estimated coefficients are consistent with expectations, and the seasonal dummies indicate that the price of peanuts is lower in the summer months through harvest time.

In summary, the results of estimating the parameters of the cottonseed oil, peanut oil, and peanut sub-model are comparable with the results of estimating the soybean, soybean oil, and soybean meal sub-model. There are, however, several important contrasts between the 2 sub-models. All derived demand elasticities for the soybean sub-model are highly inelastic. This is not true for the cottonseed oil, peanut oil, and peanut sub-model. Also, it is apparent that cottonseed oil, as a consequence of being a joint product of cotton, is an inferior good with respect to income. There were no inferior goods in the soybean, soybean oil, and soybean model. In addition, the cottonseed oil, peanut oil, and peanut sub-model seems to be not as well-specified as the soybean, soybean oil, and soybean meal model--the former having less explanatory power, more capricious estimated signs, and lower t-statistics, in general.

6.4. The Imported Oils Sub-model

The imported oils sub-model consists of 10 equations representing the domestic markets for semi-finished coconut and palm oil. The 10 equations are simultaneous and estimated by 3SLS. The quantity of each oil imported is taken as exogenous in the sub-model, and the markets for coconut and palm oil are linked simultaneously by prices. The semi-finished coconut oil market is described by 5 equations. These are the derived demand function for coconut oil used in cooking oil, the derived demand function for coconut oil used in shortening, the derived demand function for coconut oil used in margarine, identity (4.48), and an inventory-stock function. The final form of the derived demand function for coconut oil used in cooking oil is

$$(6.40)\quad q_{33}^{(1)}(t) = \underset{(498.4)}{-1897} - \underset{(.07816)}{.1427}\, p_{33}(t-2) + \underset{(.09892)}{.3246}\, p_{11}(t-2)$$

$$- \underset{(.1779)}{.1545}\, p_{12}(t-2) + \underset{(.05175)}{.7592}\, q_{33}^{(1)}(t-1) + \underset{(.002417)}{.003265}\, s_{11}(t-1)$$

$$+ \underset{(.001604)}{.003255}\, z_{11}(t-1),\ R^2 = .8820.$$

Note that all prices are lagged 2 months in this relation. This reflects the lag between ordering, receiving, and utilizing coconut oil in cooking oil. All estimated coefficients are of the appropriate sign except the lagged price of refined soybean oil. The coefficient on this variable is negative, indicating that refined soybean oil may be complementary with coconut oil. The elasticity of demand for coconut oil used in cooking oil is -.2817.

For coconut oil used in shortening, the derived demand function is

$$(6.41)\quad \underset{}{q_{33}^{(2)}(t)} = \underset{(496.7)}{-930.1} - \underset{(.08926)}{.4685}\, p_{33}(t-2) + \underset{(220.7)}{1393}\, y(t-2)$$
$$+ \underset{(.03282)}{.01676}\, p_{21}(t-2) - \underset{(.003380)}{.008286}\, z_{21}(t-1) + \underset{(.0702)}{.4997}\, q_{33}^{(2)}(t-1)$$
$$- \underset{(231.2)}{415.8}\, d_7(t),\ R^2 = .8898.$$

The derived demand function for coconut oil used in margarine is

$$(6.42)\quad q_{33}^{(3)}(t) = \underset{(167.6)}{456.6} - \underset{(.0522)}{.1016}\, p_{33}(t-2) - \underset{(51.14)}{103.9}\, y(t-2)$$
$$+ \underset{(.09992)}{.1839}\, p_{63}(t-2) + \underset{(.1100)}{.1232}\, p_{23}(t-2) + \underset{(120.2)}{213.9}\, d_2(t),\ R^2 = .5011.$$

All signs of the estimated coefficients for these 2 relations are consistent with expectations. The negative sign on income in the derived demand function for coconut oil used in margarine is not inappropriate, since coconut oil is an inferior oil in quality. As incomes rise, the demand for low-grade margarine decreases, and consequently, less coconut oil is used in margarine. This is not true of shortening even though it consists basically of low-grade fats and oils. The price elasticity of demand for coconut oil used in shortening and margarine, and the income elasticities are -.1797, -.2147, 1.1986, and -.4924, respectively.

The inventory-stock function for coconut oil is

$$(6.43)\quad p_{33}(t) = \underset{(49.56)}{145.9} + \underset{(.04109)}{.07712}\, p_{53}(t) - \underset{(.05714)}{.1933}\, p_{63}(t)$$

$$- \underset{(.001995)}{.005247} [s_{23}(t) - s_{33}(t-1)] + \underset{(.0279)}{.9960} p_{33}(t-1), \ R^2 = .9655.$$

All estimated coefficients have t-statistics greater than 2 in value and are of the appropriate sign. Note that the relation is almost unstable in a single equation context since the estimated coefficient on lagged price is .9960, and that the price of semi-finished peanut oil enters this relation as an exogenous variable.

As for the semi-finished coconut oil market, the market for semi-finished palm oil is described by 5 relations. These include derived demand functions for palm oil used in cooking oil, shortening, and margarine, identity (4.56), and an inventory-stock function. The final forms of the derived demand functions for palm oil used in cooking oil, shortening, and margarine are

$$(6.44) \quad q_{63}^{(1)}(t) = \underset{(347.0)}{205.7} - \underset{(.1780)}{.0954} p_{63}(t-1) + \underset{(.1170)}{.1235} p_{11}(t-2)$$

$$+ \underset{(140.5)}{225.8} y(t-2) - \underset{(.002110)}{.005084} z_{11}(t-1) + \underset{(.04623)}{.9179} q_{63}^{(1)}(t-1)$$

$$- \underset{(173.0)}{473.1} d_2(t) + \underset{(155.7)}{299.4} d_3(t), \ R^2 = .8592,$$

$$(6.45) \quad q_{63}^{(2)}(t) = \underset{(2858)}{4497} + \underset{(8783)}{.1049} p_{63}(t) + \underset{(776.5)}{2201} y(t) + \underset{(.7000)}{.7996} p_{53}(t)$$

$$+ \underset{(.03338)}{.9013} q_{63}^{(2)}(t-1) - \underset{(.01595)}{.07154} z_{21}(t-1) - \underset{(958.4)}{1040} d_7(t)$$

$$+ \underset{(1055)}{367.2} d_8(t) + \underset{(925.7)}{1292} d_9(t) + \underset{(926.4)}{3367} d_{10}(t), \ R^2 = .9557,$$

and

$$(6.46)\quad q_{63}^{(3)}(t) = \underset{(262.1)}{-684.0} - \underset{(.2485)}{.5909}\, p_{63}(t) - \underset{(.06135)}{.1452}\, p_{33}(t-1)$$

$$+ \underset{(.05678)}{.7345}\, q_{63}^{(3)}(t-1) + \underset{(183.4)}{518.5}\, d_2(t) + \underset{(170.6)}{338.0}\, d_8(t) - \underset{(114.3)}{43.04}\, y(t-1)$$

$$+ \underset{(.1744)}{.5884}\, p_{31}(t-1),\ R^2 = .8024.$$

The explanatory power of relations (6.44), (6.45), and (6.46) is relatively large compared with that of similar functions for other oils. However, the estimated coefficient on price in the derived demand function for palm oil used in shortening is positive. This result is perverse since the expected sign is negative. Experimental regressions using different types of lag structures for this relation all gave similar results, however, so the positive coefficient was retained. The elasticities of demand for the 3 relations are -.2583, .0112, and -1.9203, respectively. The total elasticity of demand for palm oil is -.0581. The corresponding total elasticity of demand for coconut oil is -.1987. Hence the demand for palm oil is extremely inelastic on a monthly basis--even more inelastic than the demand for coconut oil. The principal reason for this is that there is only a limited quantity of palm oil available on the domestic market in any given month. Delivery from Malayasia and other exporters generally requires 90 days. For this reason, monthly demand response is extremely inelastic.

For the inventory stock function for palm oil, the final form is

$$(6.47)\quad p_{63}(t) = \underset{(39.69)}{122.1} + \underset{(.0358)}{.8479}\, p_{63}(t-1) + \underset{(.002414)}{.00035003}\, [s_{63}(t) - s_{63}(t-1)] + \underset{(.05074)}{.2115}\, p_{13}(t) - \underset{(.01996)}{.01246}\, p_{33}(t) - \underset{(.03705)}{.09055}\, p_{41}(t),$$

$$R^2 = .9505.$$

All estimated coefficients have signs consistent with expectations, except that of coconut oil. The price of semi-finished soybean oil and the price of lard enter the relation at highly significant levels.

In summary, the derived demands for imported oils are highly inelastic, most likely because of the time lag for shipment. In terms of t-statistics, consistency of estimated signs, and explanatory power, the imported oils sub-model compares quite favorably with the other 3 sub-models of the industry. The only major problem is that the estimated price coefficient in the derived demand function for palm oil used in shortening is positive. Since this coefficient is also not significant statistically, it might be suggested that many domestic producers use a fixed percentage of palm oil in their products, with little regard for price. This prospect must be partially rejected, however, because of observed behavior in the industry--palm oil is used as an almost perfect substitute for coconut oil and lard in some finished products.

7. VALIDATION, STABILITY, AND DYNAMIC MULTIPLIERS FOR THE INDUSTRY MODEL

This section discusses the validity, the stability, and selected dynamic multipliers for the 4 sub-models presented in Section 6. Section 7.1 presents the conceptual framework used in this study for validating the industry sub-models and states explicitly the stability conditions which these sub-models must satisfy. Section 7.2 presents the results of performing a stability analysis of the 4 industry sub-models and evaluates their validity. Section 7.3 presents and discusses selected dynamic multipliers for the finished products sub-model. Section 7.4 presents and discusses selected dynamic multipliers of the soybean, soybean oil, and soybean meal sub-model. Section 7.5 presents and discusses selected dynamic multipliers of the cottonseed oil, peanut oil, and peanut sub-model, and the imported oils sub-model.

7.1. Conceptual Framework for Validation

Before an economic model can be used for simulation or policy analysis it must be validated if the results are to be accepted. The validity of any econometric model depends on its ability to explain or predict the behavior of variables in the actual system on which the model is based. Predictive accuracy can be evaluated in two ways--retrospectively and prospectively. The retrospective predictive accuracy of an econometric model relates to the model's ability to explain the behavior of endogenous variables over the sample period on which estimation is based. This is historical validation. The prospective predictive accuracy of an econometric model relates to the model's ability to explain the behavior of endogenous variables beyond the sample period on which estimation is based. This is validation by forecasting according to Naylor [45].

Consider the econometric system

$$(7.1)\quad A_1y_t + A_2y_{t-1} + A_3x_t + A_4x_{t-1} = A_0 + u_t$$

where y_t is an Nx1 vector of the values of endogenous variables at time t, y_{t-1} is the corresponding Nx1 vector of lagged values, x_t is an Mx1 vector of the values of exogenous variables at time t, x_{t-1} is the corresponding Mx1 vector of lagged values, A_0 is an Nx1 vector of intercepts, u_t is an Nx1 vector of stochastic disturbances at time t, and the A_i are matrices of estimated coefficients with row dimension N and the appropriate column dimension for each ith matrix. By rearranging terms and multiplying both sides by A_1^{-1}, it follows that

$$(7.2)\quad y_t = d_0 + D_1y_{t-1} + D_2x_t + D_3x_{t-1} + e_t, \qquad t = 1, \ldots, T.$$

Given the values of all terms on the right-hand side of this relation, y_t is exactly determined.

For purposes of validation, e_t is set equal to zero and a vector of predicted endogenous variables, $\tilde{y}_t$, is generated using

$$(7.3)\quad \tilde{y}_t = d_0 + D_1\tilde{y}_{t-1} + D_2x_t + D_3x_{t-1}, \qquad t = 1, \ldots, T.$$

The solution for $\tilde{y}_t$ over t = 1, ..., T yields the predicted retrospective time paths of the endogenous variables given the starting values for the vector of lagged endogenous variables. A solution for $\tilde{y}_t$ over $t = T + 1, \ldots, T + \Gamma$ yields the predicted prospective time paths of the endogenous variables where Γ is the number of periods beyond the original sample for which time paths are to be generated. The greater the degree to which the time path of $\tilde{y}_t$ approaches y_t for $t = 1, \ldots, T$, the greater is the validity of the model. The question to be considered is what magnitude of error is acceptable in the divergence of $\tilde{y}_t$ from y_t.

Many alternative measures for validating an econometric model have been suggested in the literature. A review of suggested methods has been presented by Naylor [46]. Most large-scale econometric models are not validated in the absolute sense--typically mean square prediction errors are compared between different models to determine which model predicts best. The problem with the mean square error statistic is that it does not allow for evaluation against a specified standard, but only for comparisons between models. Perhaps the most widely used validation statistics are the inequality coefficients proposed by Theil [61, 62]. The first inequality coefficient proposed by Theil can attain values between zero and infinity, with zero representing a perfect forecast. This coefficient has been recently criticized by Leuthold [39]. Leuthold suggests the use of another inequality coefficient proposed by Theil on the grounds that it provides more information on the accuracy of forecasts. This inequality coefficient is defined as

$$(7.4)\quad U = [\sum_{t=1}^{T} (p_t - a_t)^2 / \sum_{t=1}^{T} a_t^2]^{1/2}$$

where U is an Nx1 vector, $p_t = (\tilde{y}_t - \tilde{y}_{t-1})/\tilde{y}_{t-1}$, $a_t = (y_t - y_{t-1})/y_{t-1}$, and the powers are defined to apply to the vector elements. An absolute standard for evaluation is implied by this statistic in the following sense. If $U_i = 0$, $i = 1, \ldots, N$, then the model is predicting perfectly. If $U_i < 1$, $i = 1, \ldots, N$, then the model is performing better than no-change extrapolation. If $U_i > 1$, $i = 1, \ldots, N$, then the model is inferior to no-change extrapolation. In addition, the root mean square prediction error, represented by R, is sometimes used for making statements on the average prediction error per time period. The root mean square error is defined as

$$(7.5)\quad R = \left[\sum_{t=1}^{T} (p_t - a_t)^2/N\right]^{1/2}$$

and has the same dimension as the percentage changes p_t and a_t.

Before an econometric model can be validated it is necessary to determine whether or not the model is stable since if the system is unstable, generated time paths will explode. The stability condition for a simultaneous equation system, or the convergence condition for the total multipliers of a system of equations, requires that all roots of the D_1 matrix in relation (7.2) be less than unity in absolute value. If this condition is not met, the system is unstable, no meaningful interpretation of the interim or total multipliers can be made, and attempts to perform simulations lead to explosions in the values of the endogenous variables. In addition, an unstable system is inconsistent with the assumptions under which estimation is performed--that lagged endogenous, exogenous, and lagged exogenous variables have finite variances as $t \to \infty$. For an unstable system the variances of endogenous and lagged endogenous variables have no limit.

As indicated in Sections 5 and 6, the satisfaction of stability conditions was a criteria for the selection of the estimated relations included in each sub-model. Attempts to combine the four sub-models into a stable block-diagonal system were unsuccessful, however, because a highly unstable system resulted. This result may be attributed to misspecification of relations linking the various markets of the model, a lack of explanatory power or misspecification of the individual equations, and the difficulty of generating a large matrix which possesses characteristic roots which are all less than unity in aboslute value. The results of experimentation with alternative models and sub-models in this study indicates that it may be difficult to construct a large stable linear econometric model. This problem has been alluded to previously by Naylor [47] who references the results of a 1969 study by Cooper and Jorgenson. This study considered 7 different large-scale econometric models of the United States economy and found that the models were, in general, structurally unstable.

7.2. Validation and Stability of the Industry Sub-models

The results of determining the eigenvalues, moduli, root mean square errors, and inequality coefficients for the finished products sub-model are presented in Table 7.1. Since all moduli presented in this table are less than unity in value, the finished products sub-model is stable. The existence of negative and complex characteristic roots for the system indicates that the system oscillates with dampened cycles as it converges over time. Because one of the moduli

Table 7.1. Eigenvalues, Moduli, Root Mean Square Errors, and Inequality Coefficients for the Finished Products Sub-model

Equation Number	Eigenvalues	Modulus	Variable	R	U
1	.9999	.9999	q_{11}	.1192	.8478
2	.5881	.5881	s_{11}	.0886	.9829
3	.5503 + .5772i	.7974	z_{11}	.1486	1.0046
4	.5503 - .5772i	.7974	p_{11}	.0226	.8933
5	-.1152	.1152	q_{21}	.0982	.8552
6	.0691	.0691	s_{21}	.1119	1.0786
7	.9834	.9834	z_{21}	.1044	.9823
8	.9725	.9725	p_{21}	.0267	1.0102
9	.9742	.9742	q_{21}	.0868	.8033
10	.4847 + .5233i	.7132	s_{21}	.0997	1.0123
11	.4847 - .5233i	.7132	z_{21}	.0983	.9744
12	-.2645	.2645	p_{21}	.0233	1.0265
13	.3527	.3527	q_{91}	.0817	.5976
14	.0000	.0000	p_{91}	.0250	3.0346

is almost unity, it is apparent that this convergence is a lengthy process. With first differences in the system this is to be expected, according to Chow [10].

Regarding the validity of the finished products sub-model, the mean of the root mean square errors and the mean of the inequality coefficients for the variables in the sytem are .0810 and 1.0788, respectively. These values indicate that the model predicts the actual changes in variables of the system with a mean error of 8.1 percent per month, and that the predictive performance of the model at the mean is worse than naive no-change extrapolation. This latter conclusion must be tempered somewhat since 8 of the 14 inequality coefficients are less than unity--the poor performance in predicting the change in peanut butter price (with inequality coefficient 3.0346) causes the total performance of the model to be understated in terms of the mean inequality coefficient. The root mean square errors of the 4 price variables are lowest, with mean .0244, and the inequality coefficients for these variables are less than or only slightly greater than unity, except for peanut butter price. Hence the sub-model performs adequately with respect to the prices of cooking oil, shortening, and margarine.

Table 7.2 presents the results of calculating the eigenvalues, moduli, root mean square errors, and inequality coefficients for the soybean, soybean oil, and soybean meal sub-model. In order to perform the stability analysis, the basic sub-model as described in Section 6.2 has been augmented by the addition of the following 3 equations:

Table 7.2. Eigenvalues, Moduli, Root Mean Square Errors, and Inequality Coefficients for the Soybean, Soybean Oil, and Soybean Meal Sub-model

Equation Number	Eigenvalues	Modulus	Variable	R	U
1	.0000	.0000	$q_{12}^{(1)}$	.0900	.9082
2	.9999	.9999	$q_{12}^{(2)}$	.0903	.9034
3	.0000	.0000	$q_{12}^{(3)}$	.0947	.9330
4	.9992 + .0008i	.9992	s_{12}	.0623	1.0161
5	.9992 - .0008i	.9992	z_{12}	.0865	1.0285
6	.9335	.9335	p_{12}	.1341	1.4361
7	.8406 + .1625i	.8561	q_{13}	.1408	1.0172
8	.8406 - .1625i	.8561	s_{13}	.1486	.9988
9	.8117	.8117	p_{13}	.1772	1.7875
10	.7195	.7195	z_{13}	.1174	1.0089
11	.6473	.6473	q_{14}	.1175	1.0054
12	.6365	.6365	s_{14}	1.4753	1.0000
13	.5383	.5383	p_{14}	.0689	.9095
14	.4419 + .0257i	.4426	q_{15}	.1322	.9635
15	.4419 - .0257i	.4426	s_{15}	.1876	1.0360
16	-.3045	.3045	z_{15}	.1282	1.1355
17	.1808	.1808	p_{15}	.1022	.9673
18	.1524	.1524	p_{13}^{L}	.1843	1.8591
19	-.0709	.0709	p_{15}^{L}	.1026	.9718
20	.0000	.0000	p_{14}^{L}	.0689	.9076

(7.6) $p_{13}^{L}(t) = p_{13}(t-1)$

(7.7) $p_{15}^{L}(t) = p_{15}(t-1)$

(7.8) $p_{14}^{L}(t) = p_{14}(t-1)$

The addition of these equations is necessary to evaluate the stability of a system with endogenous variables lagged 2 periods. Once these relations have been added to the system, and the lagged endogenous variables converted to current endogenous variables using relations (7.6), (7.7), and (7.8), the stability condition is simply that the new coefficient matrix for lagged endogenous variables have all characteristic roots with absolute values less than unity. As is indicated in Table 7.2, the soybean, soybean oil, and soybean meal sub-model is stable, and will converge over time with damped oscillations and cycles.

Regarding validation, 9 of the 22 inequality coefficients for the endogenous variables of the soybean, soybean oil, and soybean meal sub-model are less than unity in value, indicating that the system prediction of these variables is superior to no-change extrapolation. Clearly this is not an especially good performance, however, 2 of the variables with inequality coefficients less than unity are the price of soybeans, p_{14}, and the price of soybean meal, p_{15}. Since these variables are of key interest in the study, it is important that the model predict these variables with a considerable degree of accuracy. For this reason, as long as the inequality coefficients are less than unity for these 2 prices, the performance of the sub-model is considered adequate.

Whether the changes in the other endogenous variables are predicted accurately is not especially relevant.

The results of evaluating the stability and validating the cottonseed oil, peanut oil, and peanut sub-model are presented in Table 7.3. The basic sub-model described in Section 6.3 has been augmented by the addition of the following equations:

(7.9) $p_{22}^{L}(t) = p_{22}(t-1)$

(7.10) $p_{23}^{L}(t) = p_{23}(t-1)$

(7.11) $p_{53}^{L}(t) = p_{53}(t-1)$

(7.12) $p_{54}^{L}(t) = p_{54}(t-1)$

As in the case of the soybean, soybean oil, and soybean meal sub-model, these relations have been added to allow the performance of stability analysis when endogenous variables lagged 2 periods are included in the sub-model. Since one of the moduli presented in Table 7.3 is equal to unity, the cottonseed oil, peanut oil, and peanut sub-model is unstable. However, the system is not far from being stable and it would take many months before the values of variables generated by the system would begin to be distorted as a consequence of explosive oscillations.

In terms of inequality coefficients, the cottonseed oil, peanut oil, and peanut sub-model is superior to the soybean, soybean oil, and soybean sub-model, and finished product sub-model--12 of 20 inequality coefficients are less than unity, and the remainder are

Table 7.3. Eigenvalues, Moduli, Root Mean Square Errors, and Inequality Coefficients for the Cottonseed Oil, Peanut Oil, and Peanut Sub-model

Equation Number	Eigenvalues	Modulus	Variable	R	U
1	1.0000	1.0000	$q_{22}^{(1)}$	.1823	.9837
2	.0000	.0000	$q_{22}^{(2)}$	.1652	.9817
3	.9605	.9605	$q_{22}^{(3)}$	.1611	.9430
4	.9237 + .2079i	.9468	s_{22}	.1747	1.0683
5	.9237 - .2079i	.9468	z_{22}	.3689	1.0020
6	.9570 + .2093i	.9796	p_{22}	.0693	.8628
7	.9570 - .2093i	.9796	q_{23}	.7640	1.0028
8	.6483	.6484	s_{23}	.3475	1.0022
9	.4566	.4566	p_{23}	.0887	.8590
10	.8615	.8615	p_{22}^{L}	.0691	.8609
11	.6254	.6254	p_{23}^{L}	.0886	.8574
12	.8169	.8169	$q_{53}^{(1)}$	.1692	.9614
13	.7580	.7580	$q_{53}^{(2)}$	- -	- -
14	.7983	.7983	$q_{53}^{(3)}$	- -	- -
15	.7372	.7372	s_{53}	.2093	1.0294
16	.0933	.0933	z_{53}	.2919	1.0070
17	.0114	.0114	p_{53}	.0632	.8831
18	.0012	.0012	q_{54}	.2602	.9022
19	.0000	.0000	s_{54}	.5168	.8388
20	-.0001	.0001	p_{54}	.0540	1.2607

Table 7.3. Continued

Equation Number	Eigenvalues	Modulus	Variable	R	U
21	.8647	.8647	p^L_{53}	.0627	.8771
22	-.0001	.0001	p^L_{54}	.0540	1.2607

not much larger than unity. No inequality coefficients are presented for $q_{53}^{(2)}$ and $q_{53}^{(3)}$ because some of the values of these 2 time series were zero. Since inequality coefficients are defined in terms of percentage changes, and a percentage change from zero to a real number is undefined, no inequality coefficients could be calculated for these variables.

For the imported oils sub-model, the results of evaluating the system for stability and validity are presented in Table 7.4. The sub-model has been augmented by the addition of 2 equations. These are:

(7.13) $p_{33}^{L}(t) = p_{33}(t-1)$

(7.14) $p_{63}^{L}(t) = p63^{(t-1)}$.

The moduli of this system, as reported in Table 7.4, indicate that the system is unstable, although it is not far from being stable (the largest modulus has value 1.0021). With respect to the validity of the model, 4 of the 12 time series have zero values for one or more observations. Hence no root mean square errors or inequality coefficients are reported for these variables. For the other variables of the system, the indications are that the sub-model predicts the price of palm oil better than no-change extrapolation, but fails to predict the price of coconut oil better than no-change extrapolation.

In summary, the 4 sub-models designed to emulate behavior in the domestic vegetable oilseeds, oils, and oil products industry are imperfect in several respects. The inequality coefficients of several

Table 7.4. Eigenvalues, Moduli, Root Mean Square Errors, and Inequality Cœfficients for the Imported Oils Sub-model

Equation Number	Eigenvalues	Modulus	Variable	R	U
1	1.0000	1.0000	$q_{33}^{(1)}$	- -	- -
2	1.0000	1.0000	$q_{33}^{(2)}$	.2633	1.0182
3	.0000	.0000	$q_{33}^{(3)}$	- -	- -
4	.6011	.6011	p_{33}	.0836	1.0030
5	.5036	.5036	s_{33}	.1695	1.0081
6	.9096	.9096	$q_{63}^{(1)}$	- -	- -
7	.6402	.6402	$q_{63}^{(2)}$	.7338	1.3711
8	1.0021	1.0021	$q_{63}^{(3)}$	- -	- -
9	.7520	.7520	p_{63}	.0732	.9250
10	.8328	.8328	s_{63}	.2276	.8551
11	.0000	.0000	p_{33}^{L}	.0836	1.0037
12	.8298	.8298	p_{63}^{L}	.0730	.9211

price variables are greater than unity. In some instances the root mean square prediction errors are excessively large. Nevertheless, the inequality coefficients and root mean square errors of the sub-models constructed in this study are generally comparable to those of other similar studies. Although there is clearly room for improvement, the inequality coefficients and root mean square errors for several key price variables are of acceptable levels.

7.3. Selected Dynamic Multipliers for the Finished Products Sub-model

The multipliers of a system of simultaneous equations consist of impact, interim, intermediate, and total multipliers (or alternatively, immediate, delayed, equilibrium, and long-run multipliers). Impact multipliers are defined as the value of dy_{it}/dx_{jt} where i and j represent the ith endogenous and jth exogenous variables of the system. Interim multipliers are defined as the value of $dy_{it}/dx_{j,t-\tau}$ where τ represents the number of lags since the jth exogenous variable was perturbed. Intermediate-run multipliers are defined as the value of $\sum_{t=1}^{\tau} (dy_{i\tau}/dx_{jt})$ where τ is the number of time periods included in the intermediate-run. Total multipliers are defined as the value of $\sum_{t=1}^{\infty} (dy_{i\infty}/dx_{jt})$, the total cumulative effect of a change in the jth exogenous variable on the ith endogenous variable over t=1, ..., ∞.

Selected interim and total multipliers for the finished products sub-model are presented in Table 7.5. Explicitly considered are unit increases in the price of semi-finished soybean oil, lard, and butter. The variables and units of measure are the same as defined in Table

Table 7.5. Selected Interim, and Total Multipliers for the Finished Products Sub-model

Endogenous Variable	Unit increase in P_{13}				Unit increase in P_{41}				Unit increase in P_{51}			
	1	2	3	Total	1	2	3	Total	1	2	3	Total
q_{11}	.15	.13	.01	-5.23	-.13	-.19	-.23	-19.28	-.19	-.18	-.08	.00
z_{11}	7.10	4.19	2.48	20.14	26.18	15.47	9.17	74.24	.00	.00	.00	.00
s_{11}	6.95	11.01	13.49	(a)	26.31	41.98	51.39	(a)	.19	.38	.46	(a)
P_{11}	.00	.00	.00	.35	.00	.01	.01	1.31	.00	.00	.00	.00
q_{21}	-.74	-.84	-.43	1.46	.03	.05	.07	5.39	.77	.88	.46	.00
z_{21}	22.69	1.45	-12.08	1.46	.00	.02	.05	5.39	-23.23	-1.48	13.12	.00
s_{21}	23.44	25.74	13.36	39.55	-.03	-.07	-.09	-3.72	-24.00	-26.36	-13.70	-41.51
P_{21}	.12	.12	.06	.00	.00	.00	.00	.00	-.12	-.13	-.06	.00
q_{31}	-.52	-.35	-.10	.00	-.01	.00	.00	.00	.54	.37	.10	.00
z_{31}	26.16	-1.26	-14.52	.00	.55	-.02	-.30	.00	-27.36	1.32	15.19	.00
s_{31}	26.68	25.77	11.35	44.84	.56	.54	.23	.94	-27.91	-26.96	-11.87	-46.90
P_{31}	.06	.05	.02	.00	.00	.00	.00	.00	-.06	-.06	-.02	.00
q_{91}	.00	.07	-.08	.00	.00	.00	.00	.00	.00	-.07	-.09	.00
P_{91}	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

4.1. A value of "a" is entered in the table for multipliers with magnitudes greater than one million. Interim multipliers are expressed for one, 2, and 3 month lags. All impact multipliers for the variables presented in Table 7.5 are zero because of the lagged structure of the equations of the sub-model.

According to the information presented in Table 7.5, a one-cent increase in the price of semi-finished soybean causes an increase in the price of shortening and margarine of .12 and .06 cents, respectively, after one month. In addition, a one-cent increase in the price of semi-finished soybean oil causes a decrease in the domestic disappearance (quantity demanded) of shortening and margarine by 74 and 52 thousand pounds, respectively. After 2 and 3 months, the effects of a one-cent increase in the price of semi-finished soybean oil are still significant, as indicated in the table. After an infinite number of months a one-cent increase in the price of semi-finished soybean oil causes a .35 cent increase in the price of cooking oil, no increase in the price of shortening or margarine, a decrease in the demand for cooking oil of 523 thousand pounds, an increase in the demand for shortening of 146 thousand pounds, an increase in the production of cooking oil of 2014 thousand pounds, an increase in the production of shortening of 146 thousand pounds, and large increases in the inventory-stock levels of cooking oil, shortening, and margarine.

For a one-cent increase in the price of lard, most of the initial effects are in the cooking oil market. After one month the result is a 13 thousand pound decrease in the demand for cooking oil, a 2618 thousand pound increase in the production of cooking oil, and a 2631 thousand pound increase in the inventory-stock level of cooking oil. After an infinite number of months the effects of a one-cent increase in the price of lard in the current month are also concentrated on the cooking oil market. A one-cent increase now leads to a decrease of 1928 thousand pounds in the demand for cooking oil, a 7424 thousand pound increase in the production of cooking oil, an increase of over a million thousand pounds in the inventory-stock level of cooking oil, a 1.31 cent increase in the price of cooking oil, a 539 thousand pound increase in the demand and production of shortening, a 372 thousand pound decrease in inventory-stocks of shortening, and a 94 thousand pound increase in the inventory-stocks of margarine, after an infinite number of months.

A one-cent increase in the price of butter causes declines in the production and storage of margarine by 2736 and 2791 thousand pounds, respectively, after one month. In addition, the price of margarine is not effected until 2 months following a one-cent increase in the price of butter--and then it declines by .06 cents. After an infinite number of months, the effect of a one-cent increase in the price of butter in the current month causes an increase in inventory-stocks of cooking oil of over one million thousand pounds, a decrease in inventory-stocks of shortening of 4151 thousand pounds, and a decrease in inventory-stocks of margarine of 4690 thousand pounds. The total multipliers of all the remaining endogenous variables in the system round off to zero. This result indicates that the response to increases in the price of butter involve ultimately the adjustment of inventory strategies in the industry as opposed to pricing strategies.

Regarding other multipliers for the finished products sub-model, the levels of the multipliers for increases in per capita income are quite interesting. The total multipliers for a thousand dollar increase in per capita income indicate that after an infinite number of months the price of cooking oil will decline by 11.65 cents, the price of peanut butter will increase by .43 cents, and there will be no effect on the price of shortening and margarine. This result is in complete contrast to that obtained by analyzing the structural income elasticities of the demand functions for these products, and suggests that basic inconsistencies may arise when dynamic multipliers are compared with structural elasticities.

In summary, the levels of the interim and total multipliers for increases in selected exogenous variables of the finished products sub-model indicate that the dynamic adjustment process is intricate and complex. In addition, the levels of the total multipliers imply that to a large extent, the adjustment process will culminate with large changes in inventory-stocks instead of prices. Furthermore, some of the indicated levels of interim and total multipliers imply adjustment processes considerably different from those implied by an analysis of static structural elasticities.

7.4. Selected Dynamic Multipliers for the Soybean, Soybean Oil, and Soybean Meal Sub-model

Table 7.6 presents the impact, interim, and total multipliers for a unit increase of one pound in foreign donations of soybean oil. As is indicated in the table, a one pound increase in donations causes an immediate increase in the level of inventory-stocks of finished soybean oil by .0281 pounds, an increase in the production of finished soybean oil by .0281 pounds, an increase in the price of finished soybean oil by .048 cents, a decrease in the level of inventory-stocks of semi-finished soybean oil by one pound, an increase in the price of semi-finished soybean oil by .052 cents, and an increase in the price of soybean meal by .0000118 cents. After one month, the effects of a one-cent increase in domestic donations in the preceding months affect every variable in the system. After 6 months, a one pound increase in foreign donations of soybean oil in the current month leads to a cummulative increase in the price of finished soybean oil of .07 cents, a cummulative decrease in the level of inventory-stocks of semi-finished soybean oil of 4.6505 pounds, and a cummulative increase in the price of semi-finished soybean oil of .066 cents (summing across the appropriate columns of Table 7.6). After an infinite number of months a one pound increase in foreign donations leads to an increase in inventory-stocks of finished soybean oil of 5.2505 pounds, a decrease in domestic disappearance of semi-finished soybean oil of one pound, and a decrease in inventory-stocks of soybeans of 91789 pounds. Hence, under the crucial assumption that the government pays the

Table 7.6. Effects of a Unit Increase in Foreign Donations of Soybean Oil on the Endogenous Variables of the Soybean, Soybean Oil, and Soybean Meal Sub-model

Endogenous Variable	Multiplier							Total
	0	1	2	3	4	5	6	
$q_{12}^{(1)}$	.0000	.0248	.0261	.0255	.0224	.0187	.0149	.0000
$q_{12}^{(2)}$	.0000	.0211	.0085	.0047	.0017	.0001	-.0008	.0000
$q_{12}^{(3)}$	.0000	.0019	.0014	.0011	.0007	.0004	.0002	.0000
s_{12}	.0281	.0479	.0750	.0952	.1074	.1116	.1095	5.2505
z_{12}	.0281	.0666	.0633	.0516	.0370	.0236	.0121	.0000
p_{12}	.0048	.0015	.0008	.0002	.0000	-.0001	-.0002	.0000
q_{13}	.0000	-.0570	.0380	.0122	.0120	.0010	-.0054	-1.0000
s_{13}	-1.0000	-.8056	-.7186	-.6230	-.5532	-.4963	-.4540	.0000
p_{13}	.0052	.0011	.0006	.0001	.0000	-.0002	-.0002	.0000
z_{13}	.0000	.1373	.1250	.1078	.0819	.0579	.0368	.0000
q_{14}	.0000	.0019	.0085	.0056	.0019	-.0019	-.0050	.0000
s_{14}	.0000	-.0019	-.0105	-.0161	-.0180	-.0161	-.0111	-91789.0000
p_{14}	.0003	.0002	.0001	.0000	.0000	.0000	.0000	.0000

Table 7.6. Continued

Endogenous Variable	Multiplier 0	1	2	3	4	5	6	Total
q_{15}	.0000	-.0010	-.0011	-.0008	-.0005	-.0003	-.0001	.0000
s_{15}	.0000	.0019	.0039	.0054	.0063	.0068	.0068	.0000
z_{15}	.0000	.0008	.0008	.0006	.0003	.0001	.0000	.0000
p_{15}	.0118	.0104	.0077	.0048	.0025	.0009	-.0002	.0000
p_{13}^{L}	.0000	.0052	.0011	.0006	.0001	.0000	-.0002	.0000
p_{15}^{L}	.0000	.0118	.0104	.0077	.0048	.0025	.0009	.0000
p_{14}^{L}	.0000	.0003	.0002	.0001	.0000	.0000	.0000	.0000

market price for semi-finished soybean oil used for donations, only inventory-stocks and domestic disappearance are effected by foreign donations in the limit.

Continuing with an analysis of selected dynamic multipliers for the soybean, soybean oil, and soybean meal sub-model, Table 7.7 presents the impact, interim, and total multipliers for a unit increase of one bushel in government stocks of soybeans. The multipliers in this table are similar to those presented in Table 7.6 except that the series of declining interim multipliers from unity is attached to soybean inventory-stocks rather than semi-finished soybean oil inventory-stocks. After an infinite number of months, a one bushel increase in government purchases of soybeans in the current month leads to an increase in inventory-stocks of semi-finished soybean oil of 61.549 pounds, a decrease in domestic disappearance of soybeans by one bushel, and a decrease in private inventory-stocks of 884100 bushels.

In summary, it is apparent that government purchases of semi-finished soybean oil and soybeans (at market prices) lead to declines in inventory-stocks of soybeans in the limit--government purchases replace private storage. In addition, government purchases reduce the domestic disappearance of each commodity by the quantity of the purchase. And, as in the case of the finished products sub-model, the levels of the multipliers over time indicate that the dynamic adjustment process is intricate and complex.

Table 7.7. Effects of a Unit Increase in Government Stocks of Soybeans on the Endogenous Variables of the Soybean, Soybean Oil, and Soybean Meal Sub-model

Endogenous Variable	Multiplier 0	1	2	3	4	5	6	Total
$q_{12}^{(1)}$	.0000	.0005	.0014	.0022	.0024	.0025	.0024	.0000
$q_{12}^{(2)}$	.0000	.0004	.0008	.0008	.0007	.0005	.0003	.0000
$q_{12}^{(3)}$	.0000	.0000	.0000	.0001	.0001	.0001	.0000	.0000
s_{12}	.0006	.0020	.0040	.0063	.0086	.0105	.0119	.0000
z_{12}	.0006	.0024	.0043	.0053	.0055	.0051	.0044	.0000
p_{12}	.0001	.0001	.0001	.0001	.0001	.0000	.0000	.0000
q_{13}	.0000	-.0013	-.0009	.0001	.0006	.0006	.0003	.0000
s_{13}	.0000	-.0178	-.0291	-.0341	-.0348	-.0330	-.0298	61.5490
p_{13}	.0001	.0001	.0001	.0001	.0001	.0000	.0000	.0000
z_{13}	.0000	-.0191	-.0121	-.0049	-.0011	.0025	.0035	.0000
q_{14}	.0000	-.0027	-.0030	-.0029	-.0028	-.0027	-.0027	-1.0000
s_{14}	-1.0000	-.9972	-.9942	-.9913	-.9884	-.9857	-.9829	-1884100.0000
p_{14}	.0002	.0001	.0000	.0000	.0000	.0000	.0000	.0000
q_{15}	.0000	-.0006	-.0006	-.0004	-.0003	-.0002	-.0001	.0000

Table 7.7. Continued

Endogenous Variable	Multiplier 0	1	2	3	4	5	6	Total
s_{15}	.0000	.0003	.0007	.0009	.0010	.0011	.0011	.0000
z_{15}	.0000	-.0003	-.0002	-.0002	-.0002	-.0001	-.0001	.0000
p_{15}	.0077	.0061	.0040	.0027	.0018	.0012	.0008	.0000
p^L_{13}	.0000	.0001	.0001	.0001	.0001	.0001	.0000	.0000
p^L_{15}	.0000	.0077	.0061	.0040	.0027	.0018	.0012	.0000
p^L_{14}	.0000	.0002	.0001	.0000	.0000	.0000	.0000	.0000

7.5. Selected Dynamic Multipliers for the Cottonseed Oil, Peanut Oil, and Peanut Sub-model

The effects of a one pound increase in foreign donations of cottonseed oil are presented in Table 7.8. Impact and interim multipliers for 6 months beyond the initial increase in foreign donations are given. Total multipliers are not presented since the cottonseed oil, peanut oil, and peanut sub-model is unstable (total multipliers are, of course, meaningless when a system is unstable). The immediate impact of an increase in foreign donations of semi-finished cottonseed oil is a decrease of one pound in inventory-stocks of semi-finished cottonseed oil, and an increase in the price of semi-finished cottonseed oil of .00006 cents. Over subsequent months a one pound increase in foreign donations in the current month causes inventory-stocks of semi-finished cottonseed oil to decline in absolute value from unity at an increasing rate. The interim multiplier effects on other endogenous variables are all relatively small, however. In addition, because the cottonseed oil markets and the peanut oil and peanut markets are contained in different simultaneous blocks in the sub-model, the effects of a one pound increase in foreign donations of semi-finished cottonseed oil on the peanut oil and peanut markets are virtually zero.

Table 7.9 presents impact and 6 months of interim multipliers for a one pound increase in government stocks of peanuts. The immediate impact of a one pound increase in government stocks of peanuts is a decrease in private inventory-stocks of 1.0015 pounds, a .00003 cent decrease in the price of semi-finished peanut oil,

Table 7.8. Effects of a Unit Increase in Foreign Donations of Cottonseed Oil on the Endogenous Variables of the Cottonseed Oil, Peanut Oil, and Peanut Sub-model

Endogenous Variable	Multiplier 0	1	2	3	4	5	6
$q_{22}^{(1)}$	.0000	-.0090	-.0153	-.0190	-.0215	-.0234	-.0249
$q_{22}^{(2)}$	.0000	-.0029	-.0053	-.0073	-.0098	-.0105	-.0119
$q_{22}^{(3)}$	.0000	-.0005	-.0008	-.0011	-.0013	-.0014	-.0016
s_{22}	.0000	.0124	.0319	.0545	.0780	.1000	.1207
z_{22}	.0000	.0000	-.0020	-.0048	-.0083	-.0129	-.0183
p_{22}	.0005	.0006	.0006	.0007	.0007	.0007	.0008
q_{23}	.0000	-.0067	-.0047	-.0075	-.0125	-.0186	-.0253
s_{23}	-1.0000	-.9932	-.9884	-.9808	-.9682	-.9495	-.9241
p_{23}	.0006	.0005	.0005	.0005	.0006	.0006	.0006
p_{22}^{L}	.0000	.0005	.0006	.0006	.0007	.0007	.0007
p_{23}^{L}	.0000	.0006	.0005	.0005	.0005	.0006	.0006
$q_{53}^{(1)}$	.0000	.0005	.0008	.0011	.0013	.0016	.0017
$q_{53}^{(2)}$	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Table 7.8. Continued

Endogenous Variable	Multiplier 0	1	2	3	4	5	6
$q_{53}^{(3)}$	.0000	.0000	.0000	.0000	.0000	.0000	.0000
s_{53}	.0000	.0005	-.0013	-.0023	-.0034	-.0044	-.0053
z_{53}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
p_{53}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
q_{54}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
s_{54}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
p_{54}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
p_{53}^{L}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
p_{54}^{L}	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Table 7.9. Effects of a Unit Increase in Government Stocks of Peanuts on the Endogenous Variables of the Cottonseed Oil, Peanut Oil, and Peanut Sub-model

Endogenous Variable	Multiplier 0	1	2	3	4	5	6
$q_{22}^{(1)}$	.0000	-.0024	-.0031	-.0032	-.0030	-.0027	-.0024
$q_{22}^{(2)}$	.0000	.0000	.0000	.0000	-.0001	-.0001	-.0002
$q_{22}^{(3)}$	.0000	.0000	.0000	.0000	.0000	.0000	.0000
s_{22}	.0000	.0024	.0055	.0084	.0106	.0121	.0127
z_{22}	.0000	.0000	-.0001	-.0004	-.0009	-.0014	-.0020
p_{22}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
q_{23}	.0000	.0000	-.0003	-.0009	-.0015	-.0022	-.0029
s_{23}	.0000	.0000	.0003	.0012	.0028	.0050	.0080
p_{23}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
p_{22}^{L}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
p_{23}^{L}	.0000	.0000	.0000	.0000	.0000	.0000	.0000
$q_{53}^{(1)}$	.0000	.0002	.0004	.0005	.0005	.0005	.0005
$q_{53}^{(2)}$	.0000	.0000	.0000	.0000	.0000	.0000	.0000
$q_{53}^{(3)}$	.0000	.0001	.0001	.0002	.0002	.0002	.0002

Table 7.9. Continued

Endogenous Variable	Multiplier						
	0	1	2	3	4	5	6
s_{53}	.0000	-.0004	-.0020	-.0039	-.0059	-.0078	-.0093
z_{53}	.0000	.0000	-.0008	-.0011	-.0011	-.0010	-.0006
p_{53}	-.0003	-.0002	-.0002	-.0001	-.0001	-.0001	-.0001
q_{54}	.0015	.0019	.0030	.0036	.0040	.0041	.0041
s_{54}	-1.0015	-.0004	-.0010	-.0006	-.0003	-.0001	-.0000
p_{54}	-.0006	-.0002	-.0002	-.0002	-.0002	-.0001	-.0001
p^{L}_{53}	.0000	-.0003	-.0002	-.0002	-.0001	-.0001	-.0001
p^{L}_{54}	.0000	-.0006	-.0002	-.0002	-.0002	-.0002	-.0001

and a .00006 cent increase in the price of shelled peanuts. These effects and those on the other endogenous variables of the system over succeeding months are relatively small, and indicate that large changes in the levels of the endogenous variables of the sub-model would occur only if large quantities of peanuts were added to or subtracted from government stocks in any single month.

One interesting result from comparing the levels of the interim multipliers for private inventory-stocks of peanuts with those of inventory-stocks of semi-finished soybean oil, soybeans, and semi-finished cottonseed oil, is that the former are very small (almost zero) over the 6 periods for which interim multipliers are reported, while the latter decline slowly from unity in absolute value as the length of lag increases. This is most likely a consequence of including government stocks of peanuts in the inventory-stock function for peanuts, while excluding government stocks or purchases from the inventory-stock functions for semi-finished soybean oil, soybeans, and semi-finished cottonseed oil. Logically, the transfer of inventory-stocks from the market to the government would constitute domestic disappearance if the inventory-stocks were donated. However, if inventory-stocks were simply carried by the government with the possibility of being returned to market at a later date, then government purchases would not constitute domestic disappearance. It follows then that changes in government stocks should enter inventory stock functions if these stocks are to be returned to market at some time in the future.

In summary, the effects of government donations of semi-finished cottonseed oil and government purchases of peanuts on the market aggregates of the sub-model are small. Large quantities of oil or peanuts would have to be purchased by the government in order to have any significant effect. The presentation of these selected multipliers for the cottonseed oil, peanut oil, and peanut sub-model concludes Section 7. No multipliers are presented for the imported oils sub-model because there are no exogenous policy or other variables of interest included in the structure of this sub-model.

8. SOME POLICY SIMULATION EXPERIMENTS WITH THE INDUSTRY SUB-MODELS

This section discusses the performance of policy simulation experiments with the model. The experiments performed are deterministic and are designed to evaluate current and recent policy alternatives which have or potentially could have implications for the vegetable oilseeds, oils, and oil products industry. Section 8.1 discusses the policy variables included in the 4 industry sub-models and reviews the role and objectives of past and prospective government policies for the industry. Section 8.2 describes the objectives of the simulation experiments. Section 8.3 reports the results of the simulation experiments and presents an overview of the consequences of alternative government policies which could have significant effects on the vegetable oilseeds, oils, and oil products industry.

8.1. Policy Variables in the Model

There are 4 control or policy variables in the 4 industry sub-models. These are government donations of soybean oil, $g_{13}(t)$; government donations of cottonseed oil, $g_{23}(t)$; the monthly change in government stocks of soybeans, $g_{14}(t)$; and the monthly change in government stocks of peanuts, $g_{54}(t)$. At present the government is actively engaged in the control of only 3 of these 4 variables: government purchases of soybean oil and cottonseed oil for foreign donation, and the monthly change in government stocks of peanuts. One other government control variable is included in the imported oils sub-model, but is not actually used for policy purposes. This is the change in bonded stocks of coconut oil, $g_{33}(t)$. This variable represents stocks of coconut oil which are resident in the United States, but for which the one-cent per pound duty has not been paid. These stocks may be re-exported or duties may be paid and the oil marketed domestically.

There are other exogenous variables in the model not currently controlled but which are potential control variables. For example, the level of imports of palm oil into the United States is not controlled currently, but this variable is a potential control variable since quotas could be introduced by the government. In addition, the levels of other exogenous variables in the system model are functions of government policy variables outside of the system. For example, the production of peanuts, $z_{54}(t)$, is a function of the announced government price support and acreage allotments. Changes in support prices or allotments effect $z_{54}(t)$. Hence the effect of changes in $z_{54}(t)$ on the system, as a consequence of policy changes outside the system, can be evaluated given the relationship between production, price supports, and acreage allotments.

Decisions on the levels of control variables in the system are generally made by Congress or government agencies on the basis of widely differing criteria. Soybean and cottonseed oil donations are made under the authority of the Agricultural Trade Development and Assistance Act of 1956--Public Law (PL) 480. Actual quantities donated are determined partially on the basis of need by the foreign country being considered, the objectives of United States foreign policy at the time, and the impacts of fairly large government purchases on domestic markets. In the late 1950's, and throughout the 1960's, PL 480 purchases of many commodities were utilized to help dispose of large agricultural surpluses accumulated under the price support program. In the early 1970's some peanut oil acquired by the Commodity Credit Corporation (CCC) under the toll crush program was donated under PL 480. The actual quantity of soybean and cottonseed oil donated under PL 480 has varied substantially from year to year, but some cottonseed and soybean oil have been donated every year since 1955, according to the Economic Research Service [71]. In recent years, however, there has been a trend towards reduced government purchases of cottonseed and soybean oil for donations. Table 8.1 gives the levels of donations, the domestic production, and the percentage of domestic production donated for soybean and cottonseed oil under PL 480 over the sample period of this study.

Although no longer actively used for control purposes, government purchases of soybeans were made in the late 1960's and early 1970's under the price support and nonrecourse loan program. With the passage of the Agricultural and Consumer Protection Act of 1973 (ACPA) soybeans were placed under the new target price and nonrecourse loan system. The ACPA specifies that when market prices fall below target prices deficiency income payments are made to producers. Nonrecourse loans are made to producers at a specified rate below the target price with the producer's commodity pledged as collateral. If producers chose not to repay the loan upon expiration, the CCC acquires the commodity. For this reason, government stocks of soybeans

Table 8.1. Foreign Donations of Soybean and Cottonseed Oil Under Assistance Programs in Thousand Pounds

Year	Soybean Oil			Cottonseed Oil		
	Quantity Donated	Domestic Production	Percentage Donated	Quantity Donated	Domestic Production	Percentage Donated
1965	186	5235	3.56	46.3	1974	2.34
1966	183	5811	3.15	1.0	1673	.06
1967	222	6150	3.61	.3	1108	.03
1968	128	6149	2.09	.1	1115	.01
1969	127	6804	1.87	.1	1425	.01
1970	129	8086	1.59	1.6	1211	.13
1971	117	8081	1.44	.0	1209	.00
1972	152	8083	1.88	.3	1355	.02
1973	93	7540	1.23	1.0	1541	.06
1974	73	8705	.84	3.8	1512	.25
1975	27	7860	.35	.2	1214	.01

Source: Economic Research Service Data Information System.

could become an active control variable again if prices were to fall sufficiently. Under ACPA no target price has been announced for soybeans, but the loan rate has been set at $2.25 in 1975 and 1976. Table 8.2 presents the price support level, the parity price level, and the season average price for soybeans, cottonseed, and peanuts from 1965 to 1975. Note that price supports were in effect for cottonseed until 1970, however, no stocks of cottonseed were acquired by the government from 1965 to 1970 since cottonseed prices were higher than support levels.

Peanuts have not been placed under the target price system established by the ACPA. The current policy for peanuts is an extension of provisions in the Agricultural Act of 1949 which established allotments, a nonrecourse loan program, and a price support system for peanuts. According to the act, quotas are established through referendums by producers. The last referendum was held in December of 1974. Quotas were approved through the 1977 crop year. Currently, as has been the case since the 1940's, peanut growers' marketing associations act as agents of the Agricultural Stabilization and Conservation Service (ASCS) in the purchase, grading, and storage of peanuts through the support program. Losses incurred by the marketing associations in maintaining support prices are absorbed by ASCS.

Prior to 1974 peanuts were sold to processors on a bid basis at prices below the loan rate. In 1974 the ASCS attempted to cut the cost of the peanut support program by requiring that 100 percent of the loan rate on diversion sales of acquired peanuts be obtained in

Table 8.2. Price Supports, Parity, and Average Seasonal Prices for Soybeans, Cottonseed, and Peanuts, 1965-1975.

	Soybeans			Cottonseed			Peanuts			
Year	Price Support	Percent of Parity	Season Average Price (per bushel)	Price Support	Percent of Parity	Season Average Price (per ton)	Price Support (per ton)	Price Support (cents per lb)	Percent of Parity	Season Average Price
1965	2.25	74	2.54	43.00	68	46.70	224.00	11.2	77	11.4
1966	2.50	78	2.75	48.00	74	65.90	227.00	11.4	77	11.3
1967	2.50	76	2.49	48.00	70	55.20	227.00	11.4	75	11.4
1968	2.50	73	2.43	48.00	69	50.50	240.25	12.0	77	11.9
1969	2.25	62	2.35	37.00	50	41.40	242.50	12.4	76	12.3
1970	2.25	61	2.85	37.00	50	56.40	255.00	12.8	75	12.8
1971	2.25	59	3.03	- -	- -	56.80	268.50	13.4	75	13.6
1972	2.25	56	4.37	- -	- -	49.50	285.00	14.3	75	14.5
1973	2.25	47	5.68	- -	- -	100.10	328.50	16.4	75	16.2
1974	2.25	38	6.64	- -	- -	135.50	366.00	18.3	75	17.9
1975	2.25	33	4.60	- -	- -	97.50	394.00	19.7	75	19.6

Source: Economic Research Service Data Information System.

resale. Peanut market prices in 1974 and 1975 were below 100 percent of the loan rate for most of each year, however, and the result was a vast accumulation of stocks under the new policy. In March of 1975 the CCC announced the initiation of a "toll" crushing program. This program allowed processors to keep the meal obtained from crushing CCC peanuts in exchange for returning the oil to the government (with some allowance to cover transportation costs). The oil was used in peanut butter and other products which were then donated to the school lunch program. In addition, as noted previously, some oil was exported under PL 480. Because of continuing oil surpluses, in November 1976 the CCC made available 130 million pounds of peanut oil for competitive bidding. The oil was restricted for use in domestic markets. Also, in November 1976 the CCC allowed peanut sales at 105-107 percent of the loan level plus carrying charges. Bids for peanuts to be exported were allowed at 100 percent of the loan rate. Any unsold peanuts remaining at the end of the year were to be sold to processors at competitive prices (Economic Research Service [71]).

8.2. The Simulation Experiments

The simulation approach to policy analysis requires the sequential solution of relation (7.3) over $t = 1, \ldots, T$. The values of exogenous and lagged exogenous variables enter the problem at their actual levels, the values of endogenous variables generated in the previous time periods are re-entered as the values of lagged endogenous variables, the levels of policy variables are specified by the analyst, and the levels of the stochastic disturbances are generated or suppressed, all for each period t over t = 1, ..., T. If stochastic disturbances are generated, the simulation is stochastic. If not, the simulation is deterministic. A comparison of simulated time paths before and after policy changes indicates the net effects of following the prescribed policies instead of the ones actually implemented.

In this section the design objectives of performing 15 policy simulations using the finished products sub-model, the soybean, soybean oil, and soybean meal sub-model, and the cottonseed oil, peanut oil, and peanut sub-model are discussed. Each simulation is completely deterministic with reduced form solutions being generated over the 136 month period for which data are available. The simulation experiments discussed in this section were designed to evaluate current policy issues and the impact of past policies which have effected the vegetable oilseeds, oils, and oil products industry. In this respect, simulation is a much more useful tool than the analysis of system multipliers--all endogenous variables are allowed to change simultaneously in response to exogenous shocks.

Four simulations were performed using the finished products sub-model. In the first 3 simulations it was assumed that tariffs of one, 2, and 3 cents were imposed on palm oil imported into the United States over the time period of the study. The possibility of imposing a tariff on palm oil has received much attention in the last two years because palm oil imports have increased drammatically. In response to congressional inquiries, two studies of the palm oil problem have been recently performed by the Economic Research Service [72] and the United States International Trade Commission [74]. On April 1, 1976 a House of Representatives bill was introduced to restore the 3 cents per pound import duty on palm oil. Much of the concern over increased palm oil importation is based on the fact that international lending institutions supported by the United States have financed much of the expansion in world production of palm oil, which competes with soybean oil. Total world production of palm oil increased from 1.7 million metric tons in 1970 to 2.9 million in 1975. Production is projected to rise to 4.3 million metric tons in 1980. United States imports of palm oil have increased from .1408 million metric tons in 1970 to .9604 in 1975. Each of 3 simulations were performed by adding one, 2, and 3 cents, respectively, to the price of palm oil over the time period of the study.

The fourth simulation experiment performed with the finished products sub-model was designed to evaluate the effects of a one-cent reduction in the price of shelled peanuts. The selection of a one-cent reduction is entirely arbitrary but consistent with future prospects for revision in the peanut program. Eventually, price supports and quota restrictions are likely to be abolished or changed so that production will be greater and prices lower. By evaluating the effects of a one-cent reduction, the results may be generalized to larger or smaller fractions.

A total of 6 simulations were performed using the soybean, soybean oil, and soybean meal sub-model. The first 3 of these simulations were designed to analyze the net effects of government purchases and sales of commodities using the sub-model. In the first simulation it was assumed that there were no government purchases of semi-finished soybean oil for foreign donation, and no government purchases or sales of soybeans under the price support system for the time period of the study. In the second simulation it was assumed that no government purchases or sales of soybeans under the price support system were allowed, but foreign donations of semi-finished soybean oil were permitted. In the third simulation it was assumed that government purchases and sales of soybeans under the price support system were allowed, but no foreign donations of semi-finished soybean oil were permitted. The first simulation was designed to evaluate the net effects of no governmental activity in the market, while the latter 2 simulations were designed to evaluate the net effects of no foreign donations, and no government purchases and sales of soybeans, independently.

The impact of the 1973 export control program for soybean and soybean meal exports was examined in the fourth simulation experiment with the soybean, soybean oil, and soybean meal sub-model. Controls were initiated on June 27, 1973 when the Secretary of Commerce imposed an embargo on the export of soybeans, soybean meal, cottonseed, and various other meal and oil products because of high domestic prices. The embargo was lifted on July 2 and replaced by a licensing procedure for exports which required contract-by-contract approval. Contracts for soybean exports were reduced 50 percent, contracts for soybean meal 60 percent, while most other export contracts were allowed to be filled at 100 percent of their original level. Under this procedure, according to the Economic Research Service [70], 33 million bushels of soybeans and 750 thousand short tons of soybean meal were exported. Export controls on soybean meal exports were lifted on September 15 and controls on soybean exports were lifted September 21.

The simulation was performed by assuming that all soybeans and soybean meal contracted for export were actually shipped. The net losses of exports as reported by the USDA were redistributed proportionately over July, August, and the part of September in which controls were in effect, to give the total amounts of exports of soybeans and soybean meal which would have been exported if controls were not applied. The actual exports of soybeans in July, August, and September were 14.237, 11.031, and 7.495 million bushels, respectively. After distributing 33 million additional bushels of soybeans over these months total exports were 26.459, 23.253, and 16.050 million bushels, respectively. Actual exports of soybean meal in July, August, and September were 1917, 3230, and 1868 thousand tons, respectively. After distributing 500 thousand additional tons of soybean meal over these months, total exports were 2117, 3430, and 1968 thousand tons, respectively. To perform the simulation, the actual quantities of soybean and soybean meal exports in July, August, and September of 1973 were replaced with the export quantities corrected for net losses due to controls and revised time paths were generated.

The fifth and sixth simulations using the soybean, soybean oil, and soybean meal sub-model were performed to determine what effect soybean exports have on domestic markets. In the fifth simulation experiment it was assumed that soybean exports were 5 percent lower over the time period of the study. In the sixth simulation experiment soybean exports were assumed to be 5 percent greater than they actually were over the time period studied. Knowledge of the impact of larger or smaller exports on domestic markets is important so that the impacts of large continuing export agreements, such as the Soviet agreement of 1975, can be evaluated.

Five simulations were performed using the cottonseed oil, peanut oil, and peanut sub-model. The first 3 of these were designed to evaluate the net effect of governmental activity on the markets for the products included in the sub-model. In the first simulation it was assumed that there were no government purchases of semi-finished cottonseed oil for foreign donation and no government purchases or sales of peanuts under the peanut price support program. In the second simulation it was assumed that no government purchases or sales of peanuts under the support program were allowed. In the third simulation it was assumed that government purchases and sales of peanuts under the price support program were allowed, but no foreign donations of semi--finished cottonseed oil were permitted. The result is that the first simulation evaluates the joint effects of no price supports for peanuts and no donations of semi-finished cottonseed oil, while the second and third simulations consider these policy alternatives independently.

The fourth and fifth simulation experiments performed with the cottonseed oil, peanut oil, and peanut sub-model were designed to analyze the potential effects of alternative government policies applied to peanut production. Since peanut production is an exogenous variable in the system model, results presented by Nieuwoudt, Bullock, and Mathia [34] in a supply response study of peanut production are utilized to perform the two experiments. Nieuwoudt, Bullock, and Mathia evaluated three alternative policies which could be implemented to control peanut production. These were a free market, a 25 percent reduction in allotments with peanuts grown on allotment acres supported at 16.2 cents per pound, and a target price program with prices supported at 15 cents per pound on 75 percent of current allotment acreage, with no support of peanuts produced on additional acres. Their results indicated that in a free market with no government price supports, acreage would increase 34 percent and prices would decline 3 cents. In a program with 25 percent reduction in allotments with supports at 16.2 cents per pound, the social cost of the program is less than that of the price support program currently utilized, assuming allotments are transferable. Under a target price program with allotments reduced to 75 percent of their current levels, with additional acreage ineligible for price supports, and with the target price of 15 cents, peanut acreage expands 44 percent.

The fourth simulation experiment was designed to partially evaluate the effects of a free market for peanuts. To perform the simulation, the Nieuwoudt, Bullock, and Mathia estimate of a 34 percent expansion in peanut acreage was taken to imply a 34 percent expansion in peanut production. The variable for peanut production in the system model, $z_{54}(t)$, was then multiplied by 1.34 at each harvest over the time period of the sample, new simulated values of the enodgenous variables of the models were generated, and government purchases and sales were set equal to zero. In the fifth simulation experiment it was assumed that quotas were reduced to three-fourths of their current level over the period of observation. In this case $z_{54}(t)$ was multiplied by .75 at each harvest to represent the probable reduction in acreage and government purchases and sales of peanuts were set equal to zero.

8.3. Results of Simulation

Table 8.3 presents the results of performing 4 simulations using the finished products sub-model. Actual and simulated means are presented, the simulated means being adjusted so that the means of simulated time paths, generated using actual values of exogenous variables, are equal to the actual means. The units of measure for each variable are the same as those given in Table 4.1. For the first, second, and third simulations, which were performed by imposing one, 2, and 3-cent tariffs on palm oil, it is immediately apparent from Table 8.3 that the introduction of a tariff has very little effect on the endogenous variables of the finished products sub-model. Prices are changed slightly, however. With a 3-cent tariff the mean price of cooking oil increases .01 cents, the mean price of shortening decreases .18 cents, and the mean price of margarine decreases .10 cents. On the basis of this information it is apparent that, if anything, the imposition of a tariff on palm oil would have had beneficial effects on consumers if implemented over the time period studied.

The finding that the imposition of a tariff on palm oil would lead to lower prices for shortening and cooking oil over the time period

Table 8.3. Results of Simulation: Means of Simulated Time Paths for the Finished Products Sub-model

Variable	Actual Means	Simulated Means for Simulation 1	2	3	4
q_{11}	263676	263665	263655	263645	263676
s_{11}	286290	286292	286293	286294	286290
z_{11}	85628	85601	85575	85548	85628
p_{11}	4597	4598	4598	4598	4597
q_{21}	199598	199634	199670	199706	199598
s_{21}	199354	199362	199369	199377	199354
z_{21}	93231	92918	92606	92293	93231
p_{21}	11001	10995	10989	10983	11001
q_{31}	185666	185688	185709	185730	185666
s_{31}	187156	187146	187137	187127	187156
z_{31}	60535	60262	59970	59717	60535
p_{31}	3632	3628	3625	3622	3632
q_{91}	46202	46196	46191	46185	46419
p_{91}	6788	6788	6788	6788	6674

studied is surprising. Normally it would be expected that imposing a tariff on one type of vegetable oil would lead to the substitution of other more expensive oils for this oil. Examining the structural production-flow functions for shortening and margarine indicates that the estimated coefficients on the price difference between semi-finished soybean oil and palm are positive (and significant)--as the price difference increases shortening and margarine production increase. In addition, since semi-finished soybean oil prices are generally greater than palm oil prices, the indications are that an increase in the price of palm oil, which decreases the price difference margin, leads to declines in the production of shortening and margarine (everything else constant). This is what would be expected, and it is clear that the results of simulation indicating slightly lower prices for shortening and margarine are a consequence of system interaction instead of an observable incorrect sign on a structural coefficient. Several of the structural coefficients in the sub-model are not statistically significant, however, so the implied results may be a consequence of misspecification.

In the fourth simulation experiment involving the finished products sub-model, the price of shelled peanuts was assumed to be one-cent lower over all months of the study. A significant decline in shelled peanut prices such as this could occur as a consequence of discontinuing the price support program for peanuts. From Table 8.3 it is apparent that a lower price for shelled peanuts has no effect on the cooking oil, shortening, and margarine markets, but has significant effects on the market for peanut butter. The mean production level of peanut butter increases from 46202 thousand pounds to 46419 thousand pounds per month in response to a one-cent reduction in shelled peanut price, and the mean price of peanut butter declines from 67.88 cents to 66.74 cents. From this result it is obvious that if large expansions in peanut production occur as a consequence of a revised peanut program, and prices decline, then consumers will benefit significantly from reduced peanut butter prices.

The results of performing the 6 simulations discussed in the previous section for the soybean, soybean oil, and soybean meal sub-model are presented in Table 8.4. The first 3 simulations were designed to analyze the joint effects of no government purchases or sales of soybeans, and no government donations of semi-finished soybean oil (simulation 1), and the disjoint effects of not allowing purchases or sales, and donations independently (simulations 2 and 3). By comparing the results for these simulations it is clear that government purchases and sales of soybeans under the price support program had a substantial effect on the endogenous market aggregates, while government purchases of semi-finished soybean oil for foreign donation had little or no effect. In simulation 2, with no government purchases or sales of soybeans under the support program, the mean price of soybeans is 3.857 dollars. This compares with an actual price of 3.890 dollars when government purchases and sales are allowed under the support program. From this it is evident that the effects of the price support program for soybeans were to increase the mean price of soybeans by 3.3 cents per bushel over the time period of the study. In addition, governmental activity in the soybean market

Table 8.4. Results of Simulation: Means of Simulated Time Paths for the Soybean, Soybean Oil, and Soybean Meal Sub-model

Variable	Actual Means	Simulated Means for Simulation 1	2	3	4	5	6
$q_{12}^{(1)}$	204948	203997	203997	204948	204956	204922	204966
$q_{12}^{(2)}$	166109	165960	165960	166109	166110	166105	166112
$q_{12}^{(3)}$	114851	114890	114890	114851	114851	114850	114852
s_{12}	280350	280766	280768	280349	280348	280359	280343
z_{12}	493492	492729	492729	493492	493499	493469	493507
p_{12}	1714	1698	1698	1714	1714	1714	1714
q_{13}	496571	497379	497382	496568	496567	496585	496557
s_{13}	375837	373354	373352	375838	375836	375826	375844
p_{13}	1513	1497	1497	1514	1514	1513	1514
z_{13}	600466	598611	598613	600464	600459	600502	600435
q_{14}	56037	55786	55786	56038	56062	56015	56034
s_{14}	87688	87973	88050	87611	87646	87987	87431
p_{14}	389.0	385.7	385.7	389.0	389.2	388.5	389.4
q_{15}	10084	10101	10101	10083	10082	10086	10082
s_{15}	2292	2254	2255	2292	2286	2297	2293
z_{15}	13275	13311	13311	13275	13280	13275	13271
p_{15}	10528	10425	10425	10528	10534	10511	10539

effected market aggregates in the semi-finished soybean oil and soybean meal markets, causing the price of semi-finished soybean oil to be .16 cents per pound greater than it would have been without government interference in the market, and the price of soybean meal to be 1.03 dollars per ton greater than would have otherwise been the case. In simulation 3, the mean levels of the endogenous variables are only slightly different from the actual means in a few cases. For this reason the effect of government purchases of soybean oil for foreign donation had an inconsequential effect on the market aggregates of the soybean, soybean oil, and soybean meal sub-model.

In the fourth simulation, the effects of the 1973 embargo on soybean and soybean meal exports were evaluated. The results of simulation, presented in Table 8.4, indicate that the imposition of export controls in 1973 over only 3 months had significant effect on the mean price levels of soybeans and soybean meal over the 136 month period of study. If no embargo had been imposed, the mean price of soybeans would have been .2 cents greater per bushel, and the mean price of soybean meal would have been 6 cents greater per ton. By multiplying these per unit losses by the total production quantities, it is apparent that the imposition of the embargo in the summer of 1973 cost producers millions of dollars. Of course, to determine the net effects of the embargo, consumer benefits from lower prices must also be considered.

The purpose of the fifth and sixth simulations using the soybean, soybean oil, and soybean meal sub-model was to evaluate the effects of soybean exports on market aggregates. To do this, in the fifth simulation it was assumed that exports were 5 percent lower over the time period of the study, while in the sixth simulation it was assumed that exports of soybeans were 5 percent greater. The results of performing these simulations are presented in the last 2 columns of Table 8.4. From the information presented in this table it is clear that if soybean exports had been 5 percent less over the study period, the mean price of soybeans would have been .5 cents lower. If soybean exports had been 5 percent greater, the mean price of soybeans would have been .4 cents higher per bushel. In addition, the price of soybean meal would have been 11 cents lower per ton with reduced soybean exports, and 11 cents greater with increased soybean exports. The prices of finished and semi-finished soybean oil would have remained virtually the same in either case.

Table 8.5 presents the results of performing 5 simulations with the cottonseed oil, peanut oil, and peanut sub-model. The first 3 simulations evaluate the net effects of government purchases of semi-finished cottonseed oil for foreign donation, and government purchases and sales of peanuts. The first simulation considers the joint effects of no government activity, the second assumes no government purchases or sales of peanuts, and the third assumes no government foreign donations of semi-finished cottonseed oil.

From the information proffered in Table 8.5 it is apparent that government donations had little effect on the price of semi-finished and finished cottonseed oil over the study period. If there had been no government purchases for foreign donations, the price of finished and semi-finished cottonseed oil would have been .03 cents lower per

Table 8.5. Results of Simulation: Means of Simulated Time Paths for the Cottonseed Oil, Peanut Oil and Peanut Sub-model

Variable	Actual Means	Simulated Means for Simulation 1	2	3	4	5
$q_{22}^{(1)}$	47283	47345	47298	47329	47298	47298
$q_{22}^{(2)}$	20335	20366	20336	20365	20336	20336
$q_{22}^{(3)}$	6058	6064	6058	6067	6058	6058
s_{22}	181956	182272	181993	182195	181993	181993
z_{22}	100273	100334	100283	100323	100283	100283
p_{22}	2100	2097	2100	2097	2100	2100
q_{23}	83546	83657	83566	83637	83566	83566
s_{23}	78285	78291	78286	78290	78290	78286
p_{23}	1727	1724	1727	1724	1727	1727
$q_{53}^{(1)}$	10417	10407	10413	10411	10413	10413
$q_{53}^{(2)}$	1367	1366	1366	1367	1366	1366
$q_{53}^{(3)}$	285	282	282	285	282	282
s_{53}	30072	30009	30014	30067	30008	30018
z_{53}	18197	18188	18195	18189	18195	18195
p_{53}	2070	2075	2075	2070	2075	2075
q_{54}	58070	57894	57894	58070	57868	57913
s_{54}	1361950	1361420	1361420	1361950	1405940	1328690
p_{54}	2305	2311	2311	2305	2313	2310

pound. For government purchases and sales of peanuts, if none had taken place over the study period the mean price of peanut oil would have been .05 cents higher and the price of shelled peanuts .06 cents higher per pound. The small levels of these changes are extremely unrealistic, however, since massive government support operations were carried out throughout the period studied. The reason for this result is that during no interval in the sample were price supports not in effect. The indicated price responses are insensitive to changes in exogenous variables because of government support programs. This is, and has been, a classic problem in estimating economic relations for controlled markets.

The fourth and fifth simulations using the cottonseed oil, peanut oil, and peanut sub-model were designed to evaluate the consequences of an expansion and contraction of peanut production as a consequence of the abrogation of the current peanut program. Again, however, the indicated price responses are unrealistic--the sub-model fails to capture price responses independent of controls. The results presented in the last 2 columns of Table 8.5 indicate that an expansion of production by one-third (the fourth simulation) and a contraction of production by one-fourth (the fifth simulation) lead to shelled peanut price increases of .08 and .05 cents per pound, respectively! Clearly this is unreasonable and it is obvious that the results generated by the cottonseed oil, peanut oil, and peanut sub-model are valid only when the peanut price support program is in effect. What is needed to evaluate the effects of supports is a sample base where supports are in effect over only a portion of the time period considered.

9. OPTIMAL CONTROL THEORY APPLIED TO AGRICULTURE AND AN EXPERIMENT IN THE OPTIMAL CONTROL OF SOYBEAN STOCKS FOR PRICE STABILIZATION

In the last few years interest in the application of optimal control theory to economic problems has received a great deal of attention in the literature. Most applications of optimal control theory have been concerned with the control of macro-econometric systems. Recent empirical studies in this area have been performed by Ando and Palash [2], Kalchbrenner and Tinsley [29], and Cooper and Fischer [13]. Major theoretical contributions in the field of optimal control have been made by Chow [9, 10, 11] and Aoki [3]. With respect to agriculture, the work by Rausser and Freebairn [51], and Freebairn [21], which analyzes adaptive control solutions for U. S. beef-trade policy, represents perhaps the most significant contribution.

This section discusses a general application of optimal control for commodity price stabilization. The direct government purchase, storage, and sale of commodities serves as the policy instrument. A hypothetical application of the proposed control program is illustrated using soybeans. Although the discussion of optimal control presented in this section is basically an appendage to the previous sections, it represents a logical extension and application using the monthly econometric model of the industry. Section 9.1 discusses control problems in general and specifies how prices of agricultural commodities might be controlled optimally to achieve price stability. Section 9.2 presents the conceptual framework for solving control problems and considers alternate solution methods. Section 9.3 discusses the results of solving for the optimal control rules to maintain price stability in the soybean market.

9.1. Control Problems, Price Stability, and a Proposal for the Control of Commodity Markets

The policy or control variables in most macro-econometric models are the money supply and government expenditures. The basic control problem is to select the levels of these variables which in some sense maximize social welfare. Typically, the maximization of social welfare is defined as the pursuit of four objectives: positive growth in national income, the maximization of employment, the minimization of growth in the inflation rate, and the realization of an equitable income distribution. These four objectives cannot be pursued individually because of the complexity and simultaneous nature of the economic system. Optimal control theory, through the incorporation of multiple objectives in an aggregate social welfare function, offers a method of selecting the optimum levels of policy variables in order to maximize social welfare.

Historically, the objective of control in the agricultural sector has been concentrated on the realization of an equitable income distribution. The other objectives of national economic control have not typically been applied in the agricultural sector, except in certain cases where tariffs or embargoes have been implemented for agricultural commodities to alleviate inflationary pressures and to maintain price stability. Of course, it may be argued that the income redistribution program implemented in the agricultural sector has also had important effects on increasing the growth in national income and maximizing the level of employment, however, the principal objective of agricultural policy as implemented by policy-makers has been income redistribution from the nonagricultural sector to the agricultural sector.

From the late 1930's until the early 1970's income redistribution was carried out in the agricultural sector under the price support program. Under price supports the government specified minimum prices for agricultural products and supported these minimums by direct purchase if market prices declined to support levels. The per unit income redistribution made under this system consisted of the difference in the support price and the market price which would have obtained if there were no government price supports. Income redistribution by this method, although politically palatable, was inefficient since income transfer from the government to agricultural producers by direct payment could be made at lower cost. A partial recognition of this fact, and the large costs of acquiring, maintaining, and dispersing stocks of commodities, led to the Agricultural Consumer Protection Act (ACPA) of 1973. As noted previously, this act provided for income redistribution to agricultural producers by direct payment when market prices fell below pre-specified target levels. However, when market prices fell below pre-specified loan levels, which were established at levels below target prices, the loan price was to be supported by direct government purchase of the commodity in question. In this respect, the fundamental provisions of the price support system were maintained in the ACPA.

Although the price support system was established primarily as a mechanism for income redistribution, there was an important secondary effect associated with the program—price stabilization. The support program led to price stability because in years of large harvests, market prices declined below support prices, the government accumulated stocks, and artifically maintained prices at levels above true market prices. In years when harvests were small, prices increased above support levels, the government sold commodities from stocks, and consequently reduced prices below market levels which would have been realized if there had been no government interference. The result was, of course, that government activity was countercyclical with respect to commodity prices, and prices were restricted within a range much smaller than would have been the case under a completely free market.

The question of whether price stability is appropriate as a policy objective has been the subject of much debate in the literature. The most recent statement on the question has been made by Turnovsky [66]. Assuming a buffer stock program with zero expected values of stock levels over time, completely linear functions, and partial equilibrium, Turnovsky concludes that, in general, price stability is beneficial to consumers and producers. This conclusion is based on the concept of producer and consumer surplus. Although some analysts may disagree with the use of this tool for policy evaluation, it is, as Currie, Murphy, and Schmitz [15, p. 791] have noted, "... difficult to find any workable alternative." For this reason it is explicitly assumed in this section that price stabilization is an appropriate policy objective, which under the appropriate circumstances generates positive net social benefits.

In order to achieve domestic price stability it is assumed in this section that a buffer stock control program is implemented. Income redistribution is assumed to be made by direct transfer payments, so price stability is the only objective of the program. The major differences in the assumed buffer stock control program and those considered previously (for example, Reutlinger [53]), are that the program is to be applied domestically, not internationally, that flexible instead of fixed decision rules are to be utilized, that embargo is reserved as a viable control policy, and that optimal control theory is utilized for making decisions under the program. The use of optimal control offers much more flexibility than the fixed decision rules proposed for use in buffer stock programs previously proposed since changes in the parameters of the aggregate social welfare function, and changes in the target prices of the optimal control problem may be made quickly when necessary.

The assumed buffer stock control program functions as follows. First, monthly target prices are specified by decision-makers. These targets may or may not be publicly announced. Second, any necessary revisions in the weights attached to a social welfare loss function, as specified by the control agency, would be made. Third, using an aggregate social welfare loss function and a monthly econometric model of the agricultural sector (or of the relevant markets), the control agency would then solve for the optimal levels of the control variables for the current month. Fourth, given the optimal control levels, the agency would then allocate purchase or sale orders to its marketing organizations.

The implementation of the control program would be advantageous in three ways. First, the control program would require that decisions be made from month to month with the levels of the control variables explicitly specified. In this respect, each monthly decision would reflect the current national economic situation, the amount of current storage capacity utilization, and current prospects for the next crop. In addition, the fact that quantity instead of price is taken as the control variable implies that the control agency would not be locked into supporting a fixed price established once a year by Congress. Second, the control program would allow for quick revisions in the program when the preferences of policy-makers change. This would be accomplished by adjusting the weights in the welfare loss function of the control algorithm. This flexibility would be particularly advantageous when new political parties are elected to office. Third, the control program could be easily integrated with national economic policy in the context of a macroeconomic control problem. Traditionally, macro-economic policy and agricultural policy have been implemented independently. In a world of increasing economic interdependence, the joint control of all domestic policy problems would be complementary and more efficient.

In contrast to the current agricultural policies, the control program would have the following advantages. First, overproduction in response to fixed minimum prices would not occur since there would be no fixed minimum prices. This fact alone would tend to make prices higher since as Sandmo [55] has demonstrated, firm output is less when prices are uncertain. Second, the physical control of stocks would be simplified since the maximum government storage capacity would be specified prior to the introduction of the control program. The government would construct and maintain the necessary storage facilities under the proposed control program. Under the current program, if market prices fall below the loan rate the government is required by law to purchase all commodities offerred at the loan price even if adequate storage facilities are not available. In the past this has led to direct payments to agricultural producers for storage of their own output.

Since the control agency would not be locked into a system of rigid purchase rules, another advantage of the control program would be that it could exert its influence to counter existing market imperfections consistent with national economic objectives. For example, the control agency could be allowed to buy and sell commodities through futures contracts. In this respect, the control agency could counter destabilizing speculative forces in the market, and force more competition in futures markets where several firms control large shares of the market. In addition, the control agency could be allowed to establish purchasing stations at spatially separated locations to breakup existing firm spatial monopolies. Also, the control agency could be allowed to sell commodities to foreign countries at market prices, discounts, or mark-ups in keeping with U. S. foreign policy. Once an export control network was established, in periods of intense export demand and high domestic prices, all exports could be required to be made through the control agency. This arrangement would assure that sales inconsistent with domestic policy would not be made by domestic corporations.

In summary, it has been assumed in effect that temporal price instability is at least a partial public good. Externalities associated with this good can be internalized by the creation of a government control agency. A control agency would use optimal control methods for making decisions and would be extremely flexible in terms of responding to changes in the objectives of policy-makers.

9.2. Conceptual Framework for the Control Problem

Consider the econometric system presented in Section 7.1:

$$(9.1)\quad y_t = d_0 + D_1 y_{t-1} + D_2 x_t + D_3 x_{t-1} + e_t$$

where the variables are defined as for relation (7.2). This system may be rewritten as

$$(9.2)\quad y_t = d_0 + D_1 y_{t-1} + [E_1\ E_2]\begin{bmatrix} g_t \\ w_t \end{bmatrix} + [E_3\ E_4]\begin{bmatrix} g_{t-1} \\ w_{t-1} \end{bmatrix} + e_t$$

where g_t is a vector of control variables, and w_t is a vector of exogenous variables not subject to control. E_1 and E_2 are matrices of estimated coefficients corresponding to the g_t and w_t vectors. The matrices E_3, and E_4 are interpreted similarly, except they apply to the lagged vectors g_{t-1} and w_{t-1}.

System (9.2) can be rewritten in terms of the endogenous and control variables as

$$(9.3)\quad z_t = C_0 z_{t-1} + C_1 g_t + c_{3t} + c_{4t}$$

where $$z_t = \begin{bmatrix} y_t \\ y_{t-1} \\ g_t \\ g_{t-1} \end{bmatrix},\quad C_0 = \begin{bmatrix} D_1 & 0 & E_3 & 0 \\ I & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & I & 0 \end{bmatrix},\quad C_1 = \begin{bmatrix} E_1 \\ 0 \\ I \\ 0 \end{bmatrix},$$

$$c_{3t} = \begin{bmatrix} b_t \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad c_{4t} = \begin{bmatrix} e_t \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

and $b_t = d_0 + E_2 w_t + E_4 w_{t-1}$. The I's represent the appropriately dimensioned identity matrices and the O's are appropriately dimensioned matrices with all zero elements.

Following Chow [10], an expected welfare loss function of the quadratic form

$$(9.4) \quad E[W] = E\left[\sum_{t=1}^{T} (z_t - a_t)' K_t (z_t - a_t)\right]$$

is defined, where a_t is a vector of target variables and K_t is a matrix of subjective weights representing the relative importance of the variables in z_t. The optimal stochastic control problem is to minimize (9.4) subject to (9.3).

The optimal control problem may be solved directly by the Lagrangian multiplier method or by dynamic programming methods. Chow has proposed a four-step iterative algorithm as the most efficient method of solution. In step 1, the following identities are defined:

$$(9.5) \quad H_T = K_T$$

$$(9.6) \quad h_T = K_T a_T \ .$$

In step 2, using the results of step 1, the J_t matrix and j_t vector are calculated using the relations

$$(9.7) \quad J_T = -(C_1' H_T C_1)^{-1} C_1' H_T C_0$$

(9.8) $j_T = -(C_1' H_T C_1)^{-1} C_1' (H_T c_{3T} - h_T).$

In step 3, the optimal levels of the control vector g_t are determined using the feedback control equation

(9.9) $g_T = J_T z_{T-1} + j_T.$

In step 4, H_{T-1} and h_{T-1} are calculated using the identities

(9.10) $H_{T-1} = K_{T-1} + C_0'H_T (C_0 + C_1J_T)$

(9.11) $h_{T-1} = K_{T-1}a_{T-1} - C_0'H_T (c_{3T} + C_1j_T) + C_0'h_T.$

The algorithm then requires a return to step 2 where the values of T are replaced with those of T-1, steps 3 and 4 are then repeated, then a return to step 2 is again required with the values for T-1 being replaced with those of T-2, and the process continued sequentially until the initial time period is reached.

It should be apparent that the solution of the optimal control problem yields a complete time series of optimal values for g_t, t=1, ..., T. The typical analytical procedure in control problems is to compare this series and the corresponding values of the endogenous variables generated by the system model, with the same values of the actual time series. By determining the value of E[W] in (9.4) for each series, given the same targets, a direct measure of the welfare gain due to optimal control is possible. Even more important is the fact that by utilizing (9.8), the control agency can determine the predicted values to be assigned to control variables in advance by solving a one period control problem for T + 1 given the appropriate predicted values of c_{3T}. This allows the control agency to engage in more efficient planning, or even to determine the values of control variables in T, when not all exogenous values are known.

For most practical applications, the derivation of the control equation (9.9) using Chow's algorithm is of only limited use since there may be inequality constraints on the levels of the control variables. Given the existence of inequality constraints on the control variables, one alternative is to solve the welfare loss minimization problem by incorporating the constraints in the problem formulation. Utilizing this approach leads to the Lagrangian function

$$(9.12)\quad L(z, \lambda, \alpha, \beta) = E \sum_{t=1}^{T} (z_t - a_t)' K_t (z_t - a_t) + \sum_{t=1}^{T} \lambda_t (y_t - C_0 y_{t-1} - C_1 g_t - c_{3t} - c_{4t}) + \sum_{t=1}^{T} \alpha_t (g_t - u_t^2 - p_t) + \sum_{t=1}^{T} \beta_t (g_t + v_t^2 - q_t)$$

where the inequality constraints $g_t \geq p_t$ and $g_t \leq q_t$ for t=1, ..., T, have been introduced with associated Lagrangian multipliers α_t and β_t, t=1, ..., T, to allow limits to be imposed on the levels of the control variables. The Kuhn-Tucker conditions for an extremum require

$$(9.13)\quad \frac{dL}{dy_t} = K(y_t - a_t) - \lambda_t + C_0 \lambda_{t+1} = 0 \qquad t = 1, \ldots, T$$

$$(9.14)\quad \frac{dL}{dg_t} = C_1 \lambda_t + \alpha_t + \beta_t = 0 \qquad t = 1, \ldots, T$$

$$(9.15)\quad \frac{dL}{d\lambda_t} = y_t - C_0 y_{t-1} - C_1 g_t - c_{3t} - c_{4t} = 0 \qquad t = 1, \ldots, T$$

$$(9.16) \quad \frac{dL}{d\alpha_t} = g_t - u_t^2 - p_t = 0 \qquad t = 1, \ldots, T$$

$$(9.17) \quad \frac{dL}{d\beta_t} = g_t + v_t^2 - q_t = 0 \qquad t = 1, \ldots, T$$

$$(9.18) \quad \frac{dL}{du_t} = -\ 2\alpha_t u_t = 0 \qquad t = 1, \ldots, T$$

$$(9.19) \quad \frac{dL}{dv_t} = -\ 2\beta_t v_t = 0 \qquad t = 1, \ldots, T$$

No simplification of this problem along the lines of the previous control solution algorithm is possible, however, and a large number of alternative solution sets must be evaluated before an optimum can be identified. For this reason programming methods offer the only realistic option.

The limitations of dynamic programming for solving problems when the number of variables and constraints is large are well known. The use of dynamic programming to solve control problems can be avoided, however, since the welfare loss minimization problem can be reformulated as a quadratic programming problem. In this respect the initial specification of the econometric system in Section 8.1. is utilized to restate the welfare loss problem as

$$(9.20) \quad \max \sum_{t=1}^{T} (a'Ka + 2y'Ka - y'Ky)$$

subject to

$$(9.21) \quad y_t = d_0 + D_1 y_{t-1} + E_1 g_t + E_3 g_{t-1} + c_{3t} + c_{4t}, \qquad t = 1, \ldots, T$$

$$(9.22) \quad g_t \geq p_t, \qquad t = 1, \ldots, T$$

$$(9.23) \quad g_t \leq q_t, \qquad t = 1, \ldots, T$$

(9.24) $g_t, y_t \geq 0,$ $\qquad t = 1, \ldots, T.$

Note that the minimization problem has been reformulated as a maximization problem, and that the levels of the control vector and vector of endogenous variables have been constrained to be nonnegative.

In summary, several methods for solving the welfare loss-control problem have been discussed. In situations where there are no constraints on variable levels in the system, the most efficient and workable solution is obtained by utilizing Chow's algorithm. In cases where there are constraints on variable levels in the system, quadratic programming provides the most efficient and workable method for obtaining a solution. In the following section, several applications are performed by applying Chow's algorithm to the soybean, soybean oil, and soybean meal sub-model.

9.3. Some Experiments in the Optimal Control of Soybean Stocks for Price Stabilization

There are 2 factors which complicate the application of optimal control for empirical experiments with the soybean, soybean oil, and soybean meal sub-model developed in this study. First, and perhaps most important, is that the method for the specification of targets as required by optimal stochastic control differs greatly from that previously (and currently) used by the government. Under the plan proposed in this study, target prices must be specified each month by the control agency, not on an annual basis (although the same target could be specified over a 12 month period). In addition, the target price under optimal control, unlike target prices in effect under current legislation, is not a minimum price which the market must reach before government intervention occurs, but rather is an exact target which is the goal of intervention. For this reason, the empirical experiments discussed in this section are based on the assumption of the existence of a control agency which sets monthly target prices in response to a Congressional mandate and acts to see that these targets are reached.

The second factor which complicates the application of optimal control for empirical experimentation with the soybean, soybean oil, and soybean meal sub-model is that there are trade-offs in the choice of the optimal control methodology to be utilized. As noted in the previous section, when there are no constraints on the limits of variables in the sub-model, then the use of the control algorithm derived by Chow is the appropriate methodological instrument. This solution method has the advantage of generating linear feedback equations for setting optimal levels of policy variables. If there are constraints on the levels of variables in the sub-model, then quadratic programming is the appropriate methodology. The use of quadratic programming does not result in linear feedback equations, however, but leads to the exact identification of the optimal control levels for policy variables for each time period considered. Quadratic programming is superior to the use of Chow's control algorithm in that once the solution is obtained, no further steps are involved. The application of the control algorithm requires that after the feedback control equations are obtained they must then be used to set the levels of the policy variables over the time period under consideration. When historical policies are to be evaluated in this way the procedure is analogous to the performance of deterministic simulations except that the levels of the control variables are set by the feedback control equation instead of being specified arbitrarily by the policy-maker.

Four optimal stochastic control experiments were performed in this study using the soybean, soybean oil, and soybean meal sub-model. In each experiment alternative target variables and policy instruments were considered. All targets were assumed to be prices and target levels were set equal to 5 month moving averages of the target time series. Hence the objective of control was to smooth prices over an intermediate time period. Because all target variables were prices, welfare weights were selected to penalize equally all dollar deviations from targets.

In the first control experiment it was assumed that the objective of control was to stabilize only the price of soybeans. The policy instrument was assumed to be government purchases and sales of soybeans on the open market. This experiment represents the simplest type of control problem--only one target and one policy variable are considered. In a control problem of this kind, when the number of targets equals the number of policy instruments, following the optimal control policy results in market prices exactly equal to target prices. In the second control experiment, 2 target prices were considered--the price of soybeans and the price of soybean meal--and one policy variable was included--government purchases and sales of soybeans. In the third optimal control experiment, 2 target prices and 2 policy instruments were considered. The targets were the price of semi-finished soybean oil and the price of soybeans, and the policy instruments were foreign donations of semi-finished soybean oil and government purchases and sales of soybeans. In the fourth control experiment, the price of soybeans and the price of soybean meal were taken as target variables, while government purchases and sales of soybeans and exports of soybean meal were selected as policy variables.

Table 9.1 presents the results of calculating the optimal feedback control equations (relation 9.9) for each of the 4 control experiments. The coefficients presented converge to steady state values after one time period. Most obvious from the information presented in the table is the fact that prices are extremely active in determining the optimal levels of the policy instruments in all 4 experiments. For the first control experiment, all signs on price coefficients are negative, with the exception of the price coefficient for semi-finished soybean oil. The combined magnitudes of the remaining price coefficients are greater, however, indicating that price increases in t imply government sales of soybeans in t + 1 as the optimal policy response, everything else constant. The signs of the coefficients on prices in t - 1, for variables p^L_{13}, p^L_{15}, and p^L_{14}, are all reversed from their signs in t, indicating a cyclical feedback response for the first control experiment. The coefficients of the feedback control equation in the second experiment, in which the price of soybean meal is added as a target, are similar in sign and magnitude to those obtained for the first control experiment except that the variables q_{15}, z_{15}, and p_{15}, and p^L_{14} more actively influence the level of the optimal policy response.

Table 9.1. Optimal Feedback Control Rules for Alternative Policy and Target Variables in the Soybean, Soybean Oil, and Soybean Meal Sub-model

Endogenous Variable	Experiment and Control Variable					
	1	2	3		4	
	g_{14}	g_{14}	g_{13}	g_{14}	g_{14}	e_{14}
$g_{12}^{(1)}$	2.743	2.743	1.788	.0000	2.748	.0044
$g_{12}^{(2)}$	1.540	1.540	1.004	.0000	1.543	-.0024
$g_{12}^{(3)}$	2.081	2.081	1.356	.0000	2.085	.0033
s_{12}	.3622	.3622	.2360	.0000	.3628	.0005
z_{12}	-3.292	-3.292	-2.145	.0000	-3.297	-.0053
p_{12}	-303.6	-303.6	-197.8	.0000	-304.1	-.4893
q_{13}	.3675	.3675	.2395	.0000	.3680	.0005
s_{13}	.0062	.0062	.0000	.0000	.0062	.0000
p_{13}	254.2	270.0	160.7	7.532	270.5	.4355
z_{13}	1.128	1.128	.7353	.0000	1.130	.0018
q_{14}	-.6162	-.6162	.0000	-.6162	-.6172	-.0009
s_{14}	.0000	.0000	.0000	.0000	.0000	.0000
p_{14}	-1221.	-1221.	-162.9	-970.9	-1221.	-1.967
q_{15}	-4.443	-13.78	.0000	-4.443	-13.80	-.0222
s_{15}	.6668	-.0334	.0000	.6668	-.0334	.0000
z_{15}	9.878	30.64	.0000	9.8783	30.69	.0494
p_{15}	-17.84	-62.58	2.243	-21.28	-62.68	-.1009
p_{13}^{L}	-1.296	-1.296	.0000	-1.296	-1.298	-.0020
p_{15}^{L}	.0014	.0014	.0000	.0014	.0014	.0000
p_{14}^{L}	29.20	90.60	.0000	29.20	90.74	.1461

In the third control experiment, target prices were p_{13} and p_{14}, and the policy instruments were g_{13} and g_{14}. The results of this control experiment are interesting because, as is indicated in Table 9.1, the levels of the coefficients of the 2 feedback control equations are vastly different. The feedback control equation for foreign donations of soybean oil does not include production, inventory-stocks, and domestic disappearance variables of the soybean and soybean meal markets, while the feedback control equation for government purchases and sales of soybeans includes no variables from the finished soybean market and omits coefficients for the derived demands for finished soybean oil. Because of the nature of these feedback control equations, large deviations in the levels of endogenous variables in one market in t - 1 may lead to large changes in the optimal policy response for one control variable in t, while the optimal policy response for the other control variable may be virtually unchanged from the preceding period. In this respect, under optimal feedback control, policy changes may be largely independent, even in an industry with integrated markets. In the fourth control experiment target prices included p_{14} and p_{15}, while policy variables were g_{14} and e_{14}. The coefficients in the feedback control equation for g_{14} are virtually identical to those for g_{14} in the second control experiment. The feedback control equations for e_{14} indicate that, unlike the situation in the third control experiment, policy changes could not occur independently in this control system since most of the coefficients in both feedback control equations are nonzero.

Actual implementation of the feedback control rules over a 36 month period from May of 1973 to April of 1976 indicated net purchases and sales of government stocks of soybeans over periods when purchases or sales would logically be expected. All 4 control experiments indicated that during the summer of 1973, a period of high prices, the optimal policy involved large sales of soybeans from stocks (assuming stocks were available prior to implementation of the control program). In 1975, after prices had declined considerably, the government became a net purchaser of soybeans. One problem indicated in the control experiments was that the optimum quantity of soybeans purchased and sold by the government in some months was extremely large--much greater than logically palatable. This result indicated that there may be some problems with the analytically derived impact multipliers for g_{14}--the soybean, soybean oil, and soybean meal sub-model may be somewhat misspecified or some parameter estimates may be biased.

In summary, the results of performing the 4 control experiments lead to feedback control equations which are consistent with expectations regarding the signs on the endogenous variables of the equations. In addition, the application of the feedback control equations over a 36 month period produces optimal policy decisions which are consistent with expectations--when prices are high the government is a net seller of soybeans, and when prices are low the government is a net purchaser. The levels of purchases and sales are extremely large in some cases, indicating the underlying econometric model may be somewhat imperfect. The use of a 5 month moving average may be somewhat responsible for this, however, and in actuality the control agency could not set targets in this way--targets would have to be specified along a time trend or an exponetial smoothing technique would have to be utilized.

10. SUMMARY AND CONCLUSION

This section summarizes the major results of the study and discusses the significant conclusions of the analysis. Section 10.1 reviews the theoretical development of the discrete dynamic market systems derived in the early part of the dissertation, elaborates on some of the problems involved in the synthesis of theory with empirical analytics, and discusses the specification, estimation, stability, and validity of the empirical model developed in this study. Section 10.2 reviews the results of the simulation experiments performed with the 4 industry sub-models and discusses the implications of alternative policies for the domestic oilseeds, oils, and oil products industry. Section 10.3 examines the potential of optimal stochastic control theory as an instrument for stabilizing agricultural prices and considers some recent criticisms of control theory.

10.1. The Theoretical Development and the Empirical Model

Inventory-stock functions are included in the model specifications of many dynamic commodity models. The theoretical foundations for this inclusion, providing an explanation of the relationship between inventory-stocks, production-flows, and other market aggregates, are far from complete. The classical theory of consumer and firm behavior is static and offers no indication of how supply flows and inventory-stocks are related. Brennan's theory of storage is incomplete because of the omission of a simultaneous role for production-flows. The operations research approach to inventory and production problems acknowledges the duality of supply flows from production and storage, but generally regards the firm's output as fixed by order receipts prior to the production period. This assumption is inconsistent with competition theorems. Samuelson and Pliska regard the duality of supply as an aggregate net social product maximization problem, but this approach does not lead to readily measurable market relations. Since none of these theoretical approaches results in a suitable dynamic theory of markets which can be implemented empirically, it is apparent that an alternative theory is necessary.

Section 3 presents an attempt to provide an alternative dynamic theory of the duality of supply. Consumers are assumed to maximize utility and producers are assumed to maximize current and expected profit simultaneously subject to budget and production constraints. Aggregation of the resultant control variable functions results in a 4-equation, simultaneous market system consisting of an aggregate demand function, an inventory-stock function, a production-flow function, and a discrete dynamic market equilibrium identity. This theoretical system is virtually identical to the simultaneous empirical systems used by Labys [33, 34] and others to describe aggregate commodity markets, and explicitly illustrates the linkage between the dynamic theoretical foundations and market empirics.

Based on the theoretical development, a model of the domestic vegetable oilseeds, oils, and oil products industry was initially specified by defining the appropriate dynamic supply identities, inventory-stock functions, production-flow functions, and demand or derived demand functions for each of 16 markets of the industry. The

16 markets were linked simultaneously, either vertically or horizontally, by the inclusion of other industry prices in the specification of each market. Attempts to estimate the complete model under the assumption that the levels of current monthly variables were sufficiently correlated with the corresponding variables of the previous month, so that lagged variables would not have to be introduced, were unsuccessful--the resulting system was unstable and not close to being stable. Consequently, the theoretical model was empiricized by including lagged variables in the relations representing the structure of the industry. The results were 4 simultaneous or block-diagonal simultaneous sub-models representing different sectors of the industry.

The final form of the empirical model, as presented in Section 6, is unpretentious and imperfect. Many estimated coefficients are insignificant by standard interpretation, the signs of some coefficients are inconsistent with expected signs, and the explanatory power of many of the estimated relations is quite poor. Despite these shortcomings, the 4 sub-models represent with some accuracy the major components of the actual systems they are designed to emulate. This is evidenced by the levels of the inequality coefficients, which to some degree are comparable with those obtained in other empirical studies such as those by Roop and Zeitner [54], and Epps [18]. Regarding the stability of the industry sub-models, 2 of the 4 sub-models are stable. The remaining 2 are not far from being stable, however, and it was deemed appropriate to retain them as presented. Although an unstable system violates the assumptions under which estimation is made, experiments conducted during the course of this study indicated that a nearly stable model typically emulated the system it was designed to model satisfactorily. This was clearly the case for the cottonseed oil, peanut oil, and peanut sub-model, which was unstable but yielded the best set of inequality coefficients of the 4 sub-models.

10.2. The Simulation Experiments

The performance of 15 simulations with 3 of the 4 industry sub-models in this study allowed for an explicit examination of policy alternatives available in the vegetable oilseeds, oils, and oil products industry. The 15 simulations were all historical--actual exogenous values were used over the period January 1965 to April of 1976. This approach was regarded as superior to postulating the future time paths of exogenous variables and simulating on this basis. An important consequence of using simulation to evaluate the effects of past policies, and the effects of alternative policies which could have been implemented, is that it allows for an explicit statement on the dollar costs and benefits of actual and alternative policies.

Based on the results of simulation, the important conclusions of this study may be summarized as follows. Regarding actual policies followed over the time period of the study, the impact of governmental activity on the vegetable oilseeds, oils, and oil products industry was significant, particularly the effects of the price support system. Governmental purchases and sales of the soybeans over the period resulted in soybean prices 3.3 cents per bushel greater at the mean level than would have resulted if no government intervention had occurred. This increase implies a gross redistribution of approximately

403.1 million real dollars from the nonagricultural to the agricultural sector, excluding government costs of redistribution, over the 136 month period studied. The higher mean price of soybeans over the period lead to higher mean prices for soybean oil and meal over the period, the final result being higher prices for finished products. Specifically, with government price supports for soybeans in effect, finished and semi-finished soybean oil prices were .16 cents higher per pound. Using simulation results (not reported in Section 8) this implies increases in the price of cooking oil, shortening, and margarine of .0324, .0067, and .0014 cents per unit, respectively. Using actual quantities of cooking oil, shortening, and margarine which would have been consumed at these lower unit mean prices, the impact on consumers of the price support system for soybeans was 13.78 million real dollars. In addition, government price support operations for soybeans increased soybean meal prices 1.03 dollars per ton at the mean level over the period. For this reason it is apparent that consumer prices for meat were higher over the period since soybean meal is an important feed ingredient. No exact value can be determined for this amount, however, since final demands for meat products are omitted from the model.

Regarding the effects of other government activity on the vegetable oilseeds, oils, and oil products industry, the results of other simulation experiments indicate that government purchases of soybean oil for foreign donation over the period had virtually no effect on industry aggregates; that the impacts of the 1973 embargo on soybean and soybean meal exports were significant, leading to mean soybean and soybean meal prices .4 per bushel and 6 cents higher per ton than would have otherwise been the case; and that government purchases of cottonseed oil for foreign donation had no effect on market aggregates of the industry. In addition, other simulation results indicate that if soybean exports had been 5 percent greater over the period studied, soybean prices would have been .5 cents higher per bushel and the price of soybean meal would have been 11 cents greater per ton at the mean level. Other simulation results indicate that the imposition of tariffs on palm oil over the time period of the study would have had little effect on the prices of finished products. Also, other simulation results indicate that lower shelled peanut prices, as a consequence of expanded peanut production and lower raw peanut prices, would significantly reduce the price of peanut butter to consumers--by 1.14 cents per pound for a one-cent decline in the price of shelled peanuts. The sub-model containing the peanut market failed to capture the effects of removing government controls on peanuts, however.

10.3. Agricultural Policy and Optimal Control

The agricultural control agency proposed in this study to implement and direct domestic agricultural policy programs is suggested, not as a viable alternative to the current system, but as one of many alternatives which should be considered given a positive decision to initiate a national program for commodity price stabilization. In the past decade many policy decisions involving price stabilization--such as the imposition of the 1973 embargo--have been made with no established criteria specifying the conditions under which the indicated action would be taken. If nothing else, the use of optimal control as a management tool to assist decision-makers requires the use of all available information and requires the decision-maker to explicitly specify the objectives of policy. The simple control experiments performed in this study indicate that the use of optimal control for stabilizing prices using different policy instruments leads to policies consistent with logical expectations--the government purchases soybeans in months when prices are low and sells from stocks in months when prices are high. It is clear, however, that a great deal of research remains to be done before a control program similar to the one examined would be workable.

The use of optimal control has been criticized by several economists. Naylor has stated that optimal control "is little more than an interesting exercise which offers only limited promise as a policy-making tool. Economists would do well to spend less time trying to specify the social welfare function of policy-makers and spend more time seeking solutions to some of the problems of policy makers [47, p. 213]." In contrast Chow states that it "is expected that the dynamic stochastic method of multiperiod control will be integrated with the main body of policy analysis" and the "important macroeconomic policy problems that can be fruitfully studied are unlimited [10, p. 223]."

Recently Kydland and Prescott [32] have criticized optimal control as being an appropriate planning device for situations in which current outcomes and the movement of the system's state depend only on current and past policy decisions, and upon the current state. Current decisions of firms and consumers depend in part on their expectations of future policy actions. In such cases, as Kydland and Prescott demonstrate, optimal control may potentially have a destabilizing effect on the system. This criticism of optimal control has some merit, since it is not difficult to imagine processing firms in the vegetable oilseeds, oils, and oil products industry adjusting their purchase and sales strategy based on their knowledge (partial or complete) of the control agency's feedback control function. The result would be that policy decisions would be suboptimal--firms would adjust purchase strategies to be consistent with their expectations of policy decisions. Kydland and Prescott's analysis, however, is based on the assumption that the constraint function for the problem (the econometric model) is nonseparable (fixed) over time. Clearly the control agency would re-estimate the econometric model over time as more data became available so that structural changes in the firm's decision-making processes would be captured in the model. This would cause the feedback control equation to be revised to reflect firm actions for each decision period. For this reason, optimal control policies would still be optimal, or at least converge toward optimality over time.

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APPENDIX A. RESULTS OF ESTIMATING THE INDUSTRY MODEL AS A COMPLETELY SIMULATNEOUS SYSTEM

As indicated in Sections 4 and 5 initial attempts were made to directly estimate the simultaneous equation model presented in Section 4 as the final form of the industry model. The 51 equations were estimated using OLS, subsystem 3SLS for each of the 16 markets included in the model, and 3SLS for the entire system. All estimates were made using SAS, which estimated all 51 equations simultaneously with less than 500K in region space on the IBM 370.

Table A.1 presents the results of evaluating the system stability for each set of estimates. Dashes are entered to represent eigenvalues which round off to zero in four decimal places. For the OLS estimates of the system, 5 of 67 eigenvalues are greater than unity in absolute value; for the subsystem 3SLS estimates 4 are greater than unity in absolute value; and for system 3SLS estimates 5 eigenvalues are greater than unity. These results indicate that for all 3 sets of estimates, the system will explode over time. Because none of the estimated parameter sets is even close to constituting a stable system, the industry model was divided into sub-models which more accurately captured the dynamics of the market system being modeled.

Table A.1. Eigenvalues of the D_1 Matrix for OLS, Subsystem 3SLS, and System 3SLS Estimates of the Parameters for the Industry Model

Equation Number	Eigenvalue for OLS	Eigenvalue for Subsystem 3SLS	Eigenvalue for System 3SLS
1	.0000	.0000	.0000
2	.0000	.0000	.0000
3	.0000	.0000	.0000
4	.0000	.0000	.0000
5	.0000	.0000	.0000
6	.0000	.0000	.0000
7	.0000	.0000	.0000
8	.0000	.0000	.0000
9	.0000	.0000	.0000
10	.0000	.0000	.0000
11	.0000	.9836	.0000
12	-4.2059	.0000	.9630
13	.9947	3.9188	.0000
14	.9062	.8827	.8874
15	.7924	.8479	.5824
16	.8715 + .1005i	3.9119	.2674
17	.8715 + .1005i	.8073	.0000
18	.8173	.6776	.9761
19	.6343	.6339	.6347
20	.8345	.7912 + .3469i	.5781
21	.6770 + .1962i	.7912 - .3469i	.7092
22	.6770 - .1962i	.7851 + .0937i	1.9879
23	.7768	.7851 - .0937i	.9105
24	.6839 + .0190i	.6714	.6677 + .1973i
25	.6839 - .0190i	.6610	.6677 - .1973i
26	-.2875 + .2506i	.1511 + .1762i	.7253
25	-.2875 - .2506i	.1511 - .1762i	.6588 + .0171i
28	.0000	.0000	.6588 - .0171i
29	.0000	.0000	-.0036
30	1.0122	.8881	.9971
31	.7192	.7710	.6599
32	.3288	.2202	.2084 + .0168i
33	.2847	-.1913	.2084 - .0168i
34	.0000	.0000	.0000
35	2.2154	.0000	.0000
36	.0000	-15.9430	3.7703
37	1.2316	7.5975	1.5598
38	1.1199	.9509 + .2753i	1.0553
39	.8547 + .2470i	.9509 - .2753i	1.0055 + .0075i
40	.8547 - .2470i	.9373 + .0487i	1.0055 - .0075i

Table A.1. Continued

Equation Number	Eigenvalue for		
	OLS	Subsystem 3SLS	System 3SLS
41	.8619 + .2451i	.9373 - .0487i	.9394
42	.8619 - .2451i	.9149 + .0940i	.8986
43	.9733	.9149 - .0940i	.7969 + .0271i
44	.9477	.8907	.7969 - .0271i
45	.9346	.8279	.7529 + .0460i
46	.9135	.8103	.7529 - .0460i
47	.8794	.8173	.7833
48	.8623	.7760	.7538
49	.8157	.6792 + .0897i	.6769
50	.6789 + .3945i	.6792 - .0897i	.5892
51	.6789 = .2945i	.4809 + .2316i	.5954 + .2660i
52	.7383	.4809 = .2316i	.5954 - .2660i
53	.6185 + .1762i	.6304	.5830 + .2497i
54	.6185 - .1762i	.6255	.5830 - .2497i
55	.6414	.5803 + .2453i	.4823 + .1936i
56	.6164	.5803 - .2453i	.4823 - .1936i
57	.2993	.3021	.4217
58	.2923	.2755 + .0831i	.4013
59	.1213 + .1322i	.2755 - .0831i	.1334
60	.1213 - .1322i	.1063	.0945 + .0476i
61	.1329	.0594	.0945 - .0476i
62	.0315	-.0567	-.0480
63	-.0123	-.0057 + .0269i	-.0058
64	.0053	-.0057 - .0269i	-.0561
65	-.0051	.0084	-.0029
66	.0664	.0000	-.0685
67	.0000	.0000	.0000

APPENDIX B. AUTOCORRELATION IN THE SYSTEM MODELS

When the disturbances of estimated relations are autocorrelated, least squares estimators are unbiased and consistent, but not efficient, and their estimated variances are biased. For this reason it is important to determine when autocorrelation is present so that the validity of t tests on regression coefficients can be considered. Traditionally, the Durbin-Watson d statistic has been used to test for autocorrelation. However, this test is invalid when lagged dependent variables are present, which is the case for all of the relations estimated in this study. As an alternative Durbin [17] has suggested the use of the h statistic, which is defined as

$$\text{(B.1)} \quad h \approx (1 - d/2)\ (n[1 - nv(b)]^{-1})^{1/2}$$

where d is the Durbin-Watson statistic, n is the number of observations in the sample, and v(b) is the estimated variance of the coefficient for the lagged endogenous variable. The statistic is tested as a standard normal deviate. If $n > 2.325$ then the hypothesis of positive first-order autocorrelation is acceptable at the 1 percent level. The 5 percent acceptance level requires that $h > 1.645$.

Table B.1 presents the d and h statistics for the equations estimated in this study (OLS estimates are used). An examination of the data in the table indicates that in 6 cases the h test cannot be applied since $nv(b) > 1$ and that in 11 of the remaining 40 cases the hypothesis of positive first-order autocorrelation is accepted at the 1 percent level. At the 5 percent level, the hypothesis of positive first-order autocorrelation is accepted in 13 of 40 cases.

Table B.1. Durbin-Watson d and Durbin L Statistics for the Estimated Relations of the Sub-models

Equation Number	d	h	nv(b)
(6.2)	1.9897	.4889	.9849
(6.3)	1.9420	.4526	.4418
(6.4)	2.3702	-3.7498	.6709
(6.5)	2.0457	-.9358	.9189
(6.6)	1.2295	4.4967	.0088
(6.7)	2.4569	-3.8704	.7069
(6.8)	2.1154	-17.0541	.9984
(6.9)	.7984	7.0009	.0058
(6.10)	2.0783	-1.3894	.9183
(6.11)	2.0171	.6360	.9756
(6.12)	1.5168	2.8101	.0021
(6.13)	2.1658	.0000	3.3318
(6.14)	2.7009	.0000	1.8987
(6.15)	2.1972	.0000	6.0432
(6.16)	2.0542	-.3322	.1006
(6.17)	1.7482	1.5888	.1526
(6.18)	2.5111	.0000	2.9428
(6.19)	1.4139	12.1184	.9210
(6.20)	2.4941	-4.1840	.3197
(6.21)	2.3681	-3.3095	.5827
(6.22)	1.5942	2.7392	.2538
(6.23)	2.2704	3.0763	.7392
(6.24)	1.7137	.0000	1.5513
(6.25)	2.4824	3.5256	.3679
(6.26)	2.322	1.8663	.5209
(6.27)	2.2191	1.4471	.2326
(6.28)	1.9971	.0360	.7666
(6.29)	2.0885	.5404	.0945
(6.30)	1.6894	2.2568	.3689
(6.31)	1.9795	.0000	1.8511
(6.32)	2.2661	-1.6463	.1189
(6.33)	2.3499	-2.7234	.4432
(6.34)	2.1976	-1.8018	.5941
(6.35)	1.6313	2.8364	.4294
(6.36)	1.6545	2.0558	.0462
(6.37)	1.4825	3.8524	.3907
(6.38)	1.5786	3.9092	.6078
(6.39)	1.7462	1.5484	.0918
(6.40)	2.4281	-3.2976	.4309
(6.41)	2.4988	-3.9094	.4465
(6.42)	2.6502	-.5206	.6862

Table B.1. Continued

Equation Number	d	h	nv(b)
(6.43)	1.3217	6.5747	.6381
(6.44)	2.7486	-5.4167	.3552
(6.45)	1.8483	1.0688	.3201
(6.46)	2.4995	-5.0894	.6747
(6.47)	1.7191	1.6917	.0696

It should be noted that a test for autocorrelation has been recently proposed by Godfrey [24] which does not have the disadvantages of being inconclusive when the value of nv(b) is greater than unity, as in the Durbin h test. The computation of the test statistic requires the revision of the 2SLS program used for estimation, however. This alteration has not been attempted in this study largely because the Durbin h test is sufficient to illustrate the presence of autocorrelation in the system.

APPENDIX C. SOURCES OF DATA

The principal data source utilized in this study was the Economic Research Service Data Information System (DIS), an automated tape-storage library. The Economic Research Service compiles and maintains mostly secondary-source data on the system, their major sources being census publications, other USDA publications, and trade publications. Other information used in this study was obtained from a variety of sources. Data sources for variables not obtained from DIS are presented in Table C.1.

As in the case of most empirical studies there are clearly deficiencies in the data used in this study. In some cases monthly DIS price series show the same price for a single product over 3 months during periods when the prices of substitutes changed considerably. Much of the information in DIS on monthly price series comes from trade publications, however. Telephone conversations with the individuals responsible for the collection of data for one trade publication indicated that price series were compiled by contacting one firm which produced the product and obtaining the firm's end-of-the-month price. Clearly the use of a single firm's price as an approximation of the national average price is inappropriate. This same type of simplification seems to be present in several other DIS price series. Alternative time series were not available, however, and the utilization of the existing data base represented the only appropriate course of action.

Table C.1. Data Sources for Variables not Included in the Economic Research Service Data Information System

Variable	Specification and Source
$E[p_{13}]$	End-of-month price, third-near futures contract, soybean oil, Wall Street Journal.
$E[p_{14}]$	End-of-month price, third-near futures contract, soybeans, Wall Street Journal.
$E[p_{15}]$	End-of-month price, third-near futures contract, soybean meal, Wall Street Journal.
q_{81}	Monthly civilian population from Population Estimates and Projections, Bureau of Census, U. S. Department of Commerce, Washington, D.C.
p_{71}	Monthly average interest rate on 4-6 month commercial paper, from the Federal Reserve Bulletin, Board of Governors of the Federal Reserve System, Washington, D.C.
y	Monthly personal income on annual basis, from the Federal Reserve Bulletin.
g_{14}^{L}	Monthly uncommitted government stocks of soybeans, from mimeographed report, Agricultural Conservation and Stabilization Service, U.S.D.A., Washington, D.C.
g_{15}^{L}	Monthly uncommitted government stocks of peanuts, from Peanut Stocks and Processing, Crop Reporting Board, Statistical Reporting Service, U.S.D.A., Washington, D.C.

APPENDIX D. THE FORTRAN PROGRAM

Perhaps the most important contribution of this study was the development of a general-purpose fortran program for policy analysis using large-scale econometric models. Once the structural parameters are read into the program and the data set made available, the program may be used (1) to calculate impact, interim, and total system multipliers; (2) to calculate retrospective or prospective inequality coefficients, count the percentage of correctly predicted turning points, calculate inequality proportions, and calculate optimal linear corrections for predictions; (3) to perform multiple simulations using linear transforms of exogenous variables, linear feedback rules, or other alterations of the model; and (4) to calculate the optimal control rules for an optimal control problem with quadratic welfare loss function and a linear econometric system.

The program was written using University of Waterloo Fortran (WATFIV) and checked computationally when possible using the matrix language feature of SAS. The entire program is written in double precision. Extensive test comparisons of a single precision version of the program with SAS (double precision) programs indicated that the single precision program developed for this study was generally accurate to only three or four significant places. For this reason, the double precision version is necessary for practical applications even though it requires significantly greater region space (499K for a system with 22 equations and 46 variables).

So that any reader may implement the program developed for this study, a list of the parameters utilized in the program is presented in Table D.1. The notation in the definitions of each parameter is consistent with that presented in the text. A complete listing of the source program follows Table D.1. Relevant explanatory notes are made throughout the program. Several standard IBM scientific subroutines utilized by the program are listed since several minor alterations have been made.

Table D.1. Control Parameters in the Program

Parameter Number	Value of Parameters	Definition of Parameter Response
1	0–∞	Number of problems to be analyzed
2	1	Calculate dynamic multipliers
3	1	Perform retrospective validation
4	1	Perform prospective validation
5	1	Perform simulation
6	0–67	Number of rows in A
7	0–49	Number of columns in D_2
8	1	Print eigenvalues of D_2 matrix
9	1	Print d_o vector, D_1, D_2, and D_3 matrices
10	1	Evaluate a second set of estimated coefficients
	2	Evaluate a third set of estimated coefficients
11	1–∞	Number of periods of interim multipliers to be calculated
12	1	Print first observation values
13	1–∞	Number observations in retrospective validation or simulation
14	1–∞	Number of observations in prospective validation
15	1	Print actual and predicted time paths for validation
16	1	Correct inequality coefficients using optimal linear transformation for retrospective validation
17	1	Correct inequality coefficients using optimal linear transformation for prospective validation

Table D.1. Continued.

Parameter Number	Value of Parameters	Definition of Parameter Response
18	1–∞	Number of simulations to be performed
19	1	Print simulated time paths
20	1	Print D_2 matrix even if system is unstable
21	0	Dummy variable
22	1	Adjust data by a linear transform
23	1	Apply optimal linear transform calculated for retrospective validation to prospective validation
24	1	Perform turning point analysis and print inequality proportions
25	1	Derive an optimal linear transformation rule to force the simulated means to equal actual means of the observed time series
26	1–∞	Number of format cards
27	1	Use observed values of lagged endogenous variables -- no feedback
28	1	Use subset of data set for all operations beginning with observation indicated in control parameter 29
29	1–∞	Observation number for beginning of data subset
30	1	Actual means, standard deviations, and variances are not calculated for the simulation

```
      INTEGER N(35),M(20),I1/'    '/,I2/'PROG'/,I3/'RAM '/,I4/'PARA'/,I5
     1/'METE'/,I6/'RS'/
      DIMENSION D0(32),D1(32,32),D2(32,35),D3(32,35),A(32,32),E0(32),E1(
     132,32),E2(32,35),E3(32,35)
      DOUBLE PRECISION A,D0,D1,D2,D3,E0,E1,E2,E3
      COMMON/T1/N/T2/M/T4/II/T3/ID
      ID=1
      II=0
      NRT=0
    2 II=II+1
      READ(5,1)(N(I),I=1,35)
      IF(N(21).EQ.0)READ(5,3)(M(I),I=1,20)
      CALL TITLE(I1,I1,I1,I2,I3,I4,I5,I6,I1,I1)
      WRITE(6,10)(N(I),I=1,35)
   10 FORMAT(' ',/2X,'NUMBER OF PROBLEMS                         ',I3,
     1/2X,'CALCULATE DYNAMIC MULTIPLIERS        ',I3,
     1/2X,'PERFORM RETROSPECTIVE VALIDATION     ',I3,
     1/2X,'PERFORM PROSPECTIVE VALIDATION       ',I3,
     1/2X,'PERFORM SIMULATION(S)                ',I3,
     1/2X,'NUMBER OF ENDOGENOUS VARIABLES       ',I3,
     1/2X,'NUMBER OF EXOGENOUS VARIABLES        ',I3,
     1/2X,'PRINT EIGINVALUES FOR D1             ',I3,
     1/2X,'PRINT E0,E1,E2,E3,D0,D1,D2,D3        ',I3,
     1/2X,'LOCATION OF MATRIX ELEMENTS          ',I3,
     1/2X,'NUMBER OF INTERIM MULTIPLIERS        ',I3,
     1/2X,'PRINT FIRST OBSERVATION VALUES       ',I3,
     1/2X,'NO OF OBS IN RETRO OR SIMULATION     ',I3,
     1/2X,'NO OF OBS IN PROSPECTIVE VALIDATION',I3,
     1/2X,'PRINT VALIDATION TIME PATHS          ',I3,
     1/2X,'CORRECT RETRO CHANGES                ',I3,
     1/2X,'CORRECT PROSPECTIVE CHANGES          ',I3,
     1/2X,'NUMBER OF SIMULATIONS                ',I3,
```

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      1/2X,'PRINT SIMULATED TIME PATHS              ',I3,
      1/2X,'OVER-RIDE STABILIZATION CONDITION       ',I3,
      1/2X,'RE-USE PREVIOUS D0,D1,D2,D3             ',I3,
      1/2X,'MAKE ADJUSTMENTS TO DATA                ',I3,
      1/2X,'APPLY RETRO CORRECTION TO PROSP         ',I3,
      1/2X,'PRINT TURN POINT AND REGR PERCENTS      ',I3,
      1/2X,'COMPUTE OPTIMAL LEVEL CORRECTIONS       ',I3,
      1/2X,'NUMBER OF FORMAT CARDS                  ',I3,
      1/2X,'USE ACTUAL Y VALUES FOR COMPUTATION     ',I3,
      1/2X,'USE INTERVAL OBSERVATIONS               ',I3,
      1/2X,'INTERVAL OBSERVATION ORIGIN             ',I3,
      1/2X,'CALULATE ACTUAL MEANS (SIMULATION)      ',I3,
      1/2X,'PRINT TARGET IDS AND TARGETS            ',I3,
      1/2X,'PRINT G,GV,Y                            ',I3,
      1/2X,'DUMMY                                   ',I3,
      1/2X,'PRINT H,B,HV,-CT*H*C,ETC.               ',I3,
      1/2X,'PRINT B,A,C                             ',I3)
       WRITE(3,20)
 20    FORMAT(' ',///2X,'LINEAR SYSTEMS ANALYSIS PROGRAM DESIGNED BY:',
      1//12X,'R MCFALL LAMM JR',/12X,'ECONOMIC RESEARCH SERVICE',/12X,'D
      1EPARTMENT OF AGRICULTURAL ECONOMICS',/12X,'VPI&SU, BLACKSBURG, VA
      124061',///2X,'LAST REVISION: 6/30/77')
       N1=N(6)
       N2=N(7)
       IF(N(33).GT.0)N(13)=N(13)-N(33)
  1    FORMAT(I3,4I1,2I3,3I1,I3,I1,2I3,3I1,I3,7I1,I3,2I1,I3,6I1)
  3    FORMAT(20A4)
       IF(N(21).EQ.1)NPT=1
       N(21)=0
       N(33)=1
       CALL INIT(A,D0,D1,D2,D3,F0,E1,E2,E3,N1,N2,NRT)
       IF(II.EQ.1)K=N(1)
```

```
      IF(II.LT.K)GO TO 2
      STOP
      END
C
C SUBROUTINE INIT COMPUTES SYSTEM INVERSE AND INITIALIZES SUBROUTINES TO
C PERFORM REQUIRED OPERATIONS ON THE ECONOMETRIC SYSTEM
      SUBROUTINE INIT(A,D0,D1,D2,D3,E0,E1,E2,E3,N1,N2,NRT)
      REAL*8 A(N1,N1),D0(N1),D1(N1,N1),D2(N1,N2),D3(N1,N2),E0(N1),E1(N1,
     1N1),E2(N1,N2),E3(N1,N2),D
      DIMENSION L(48),M(35)
      INTEGER N(35)
      INTEGER K1/' A M'/,K2/'ATRI'/,K3/'E0 V'/,K4/'ECTO'/,K5/'R TR'/,K6/
     1'E2 M'/,K7/'E3 M'/,K8/'E1 M'/,K9/'    '/,K10/'X'/,K11/'ANSP'/,K12/'OS
     1E '/,K13/'D0 V'/,K14/'D1 M'/,K15/'D2 M'/,K16/'D3 M'/
      COMMON/T1/N/T5/ID/T6/L/T7/M
      IF(NRT.EQ.1)GO TO 3
      CALL RM(A,N1,N1)
      CALL RV(E0,N1)
      CALL RM(E1,N1,N1)
      CALL RM(E2,N1,N2)
      CALL RM(E3,N1,N2)
      IF(N(3)+N(4)+N(5)+N(31).EQ.0)GO TO 91
      CALL COUNT(E1,N1,N1)
      CALL COUNT(E2,N1,N2)
      CALL COUNT(E3,N1,N2)
      REWIND 10
   91 IF(N(9).NE.1)GO TO 1
      CALL PM(A,N1,N1,K9,K9,K9,K9,K1,K2,K10,K9,K9,K9)
      CALL PV(E0,N1,K9,K9,K9,K3,K4,K5,K11,K12,K9,K9)
      CALL PM(E1,N1,N1,K9,K9,K9,K9,K8,K2,K10,K9,K9,K9)
      CALL PM(E2,N1,N2,K9,K9,K9,K9,K6,K2,K10,K9,K9,K9)
      CALL PM(E3,N1,N2,K9,K9,K9,K9,K7,K2,K10,K9,K9,K9)
```

```
  1   CALL MINV(A,N1,D,L,M)
      IF(D.LE.0.00001.AND.D.GE.-0.00001)GO TO 2
      CALL GMPRD(A,E1,D1,N1,N1,N1)
      CALL GMPRD(A,E2,D2,N1,N1,N2)
      CALL GMPRD(A,E3,D3,N1,N1,N2)
      CALL MVPRD(A,E0,D0,N1,N1)
      IF(N(9).NE.1)GO TO 90
      CALL PV(D0,N1,K9,K9,K9,K13,K4,K5,K11,K12,K9,K9)
      CALL PM(D1,N1,N1,K9,K9,K9,K9,K14,K2,K10,K9,K9,K9)
      CALL PM(D2,N1,N2,K9,K9,K9,K9,K15,K2,K10,K9,K9,K9)
      CALL PM(D3,N1,N2,K9,K9,K9,K9,K16,K2,K10,K9,K9,K9)
 90   IF(N(2).NE.1)GO TO 3
      ID=2
      DO 5 I=1,N1
      WRITE(3,4)(D2(I,J),J=1,N2)
  5   WRITE(3,4)(D3(I,J),J=1,N2)
      REWIND 3
      CALL DYMULT(D1,D2,D3,E1,E2,E3,N1,N2,E0)
  4   FORMAT(6E12.5)
      DO 6 I=1,N1
      READ(3,4)(D2(I,J),J=1,N2)
  6   READ(3,4)(D3(I,J),J=1,N2)
      REWIND 3
      GO TO 3
  2   WRITE(6,11)D
 11   FORMAT(' ',//2X,'DETERMINANT A',F20.6//)
      RETURN
  3   NT=N(13)
      ID=3
      IF(N(22).NE.0)CALL REVISE(A,N1,D0,D1,D2,D3,E0,E1,E2,E3,N2,NT,NRT)
      DO 14 J=1,2
      DO 14 I=1,N1
```

```
14    A(J,I)=0.
      IF(N(3).NE.1)GO TO 10
      NN=0
      CALL VALID(D0,D1,D2,D3,N1,N2,E0,E1,E2,E3,NN,NT,A,NRT)
10    ID=4
      NN=0
      NT=N(14)
      IF(N(4).NE.1)GO TO 12
      CALL VALID(D0,D1,D2,D3,N1,N2,E0,E1,E2,E3,NN,NT,A,NRT)
12    IF(N(5).NE.1)GO TO 13
      ID=5
      NT=N(13)
      CALL SIMULT(D0,D1,D2,D3,E0,E1,E2,E3,N1,N2,NT,A)
13    IF(N(31).EQ.0)GO TO 15
      CALL CNTRL(D0,D1,D2,D3,E0,E1,E2,E3,N1,N2,A)
15    RETURN
      END
C
C SUBROUTINE DYMULT COMPUTES IMPACT, INTERIM, AND TOTAL MULTIPLIERS
      SUBROUTINE DYMULT(D1,D2,D3,E1,E2,E3,N1,N2,E0)
      REAL*8 D1(N1,N1),D2(N1,N2),D3(N1,N2),E1(N1,N1),E2(N1,N2),E3(N1,N2)
     1,E0(N1)
      DIMENSION L(48),M(35),R1(48),R2(48),R3(35)
      DOUBLE PRECISION R1,R2,R3,D
      INTEGER N(35)
      INTEGER K1/' EIG'/,K2/'ENVA'/,K3/'LUES'/,K4/' IMPA'/,K5/'CT M'/,K6/
     1'ULTI'/,K7/'PLIE'/,K8/'RS'/,K9/'    I'/,K10/'NTER'/,K11/'IM M'/,K12
     1/' TOT'/,K13/'AL M'/,K0/' '/
      COMMON/T6/L/T7/M/T1/N/T30/R1/T31/R2/T32/R3
      NS=0
      DO 1 I=1,N1
      DO 1 J=1,N1
```

```
  1   E1(I,J)=D1(I,J)
      CALL HSBG(N1,E1,N1)
      CALL ATEIG(N1,E1,R1,R2,R3,N1)
      DO 2 I=1,N1
      R3(I)=R1(I)**2+R2(I)**2
      R3(I)=DSQRT(R3(I))
  2   IF(R3(I).GE.1.)NS=1
      IF(N(8).NE.1)GO TO 3
      CALL TITLE(K0,K0,K0,K0,K1,K2,K3,K0,K0,K0)
      WRITE(6,50)
 50   FORMAT(' ','REAL COMPONENT'/)
      WRITE(6,4)(R1(I),I=1,N1)
  4   FORMAT(' ',10(1X,G12.5))
      WRITE(6,5)
  5   FORMAT(' ',/1X,'IMAGINERY COMPONENT'/)
      WRITE(6,4)(R2(I),I=1,N1)
      WRITE(6,51)
 51   FORMAT(' ',/1X,'MODULUS'/)
      WRITE(6,4)(R3(I),I=1,N1)
  3   IF(NS.EQ.1)GO TO 28
 33   CALL PM(D2,N1,N2,K0,K0,K0,K4,K5,K6,K7,K8,K0,K0)
      DO 6 I=1,N1
      DO 6 J=1,N1
  6   E1(I,J)=D1(I,J)
      NT=N(11)
      DO 7 I=2,NT
      IF(I.GE.3)GO TO 13
      CALL GMPRD(D1,D2,E2,N1,N1,N2)
      CALL MSUM(E2,D3,N1,N2)
      IF(I.EQ.2)GO TO 30
 31   CALL MSUM(D2,D3,N1,N2)
      GO TO 7
```

```
13   IF(I.EQ.3)GO TO 40
     CALL SQPRD(D1,E1,E0,N1)
40   CALL GMPRD(E1,E2,D3,N1,N1,N2)
30   CALL TITLE(K0,K0,K9,K10,K11,K6,K7,K8,K0,K0)
     III=I-1
     WRITE(6,14)III
14   FORMAT(' ',35X,'MATRIX OF INTERIM MULTIPLIERS AFTER ',I2,' TIME PE
    1RIOD(S)'/)
     DO 15 II=1,N1
     IF(I.GE.3)WRITE(6,16)(D3(II,J),J=1,N2)
     IF(I.EQ.2)WRITE(6,16)(E2(II,J),J=1,N2)
16   FORMAT(10(1X,G12.5))
15   WRITE(6,17)
17   FORMAT(' ')
     IF(I.EQ.2)GO TO 31
 7   CONTINUE
     DO 19 I=1,N1
     DO 20 J=1,N1
20   E1(I,J)=0.
19   E1(I,I)=1.
     CALL MSUB(E1,D1,N1,N1)
     CALL MINV(E1,N1,D,L,M)
     CALL GMPRD(E1,D2,D3,N1,N1,N2)
     CALL PM(D3,N1,N2,K0,K0,K0,K12,K13,K6,K7,K8,K0,K0)
     GO TO 25
28   WRITE(6,24)
24   FORMAT(' ',/2X,'SYSTEM UNSTABLE'/)
     IF(NS.EQ.1.AND.N(20).EQ.1)GO TO 33
25   RETURN
     END
C
C SUBROUTINE VALID COMPUTES INEQUALITY COEFFICIENTS, INEQUALITY PROPORTI
```

```
C ONS, AND COUNTS NO OF TURNING POINTS
      SUBROUTINE VALID(D0,D1,D2,D3,N1,N2,E0,E1,E2,E3,NN,NT,A,NRT)
      REAL*8 D0(N1),D1(N1,N1),D2(N1,N2),D3(N1,N2),E0(N1),E1(N1,N1),E2(N1
     1,N2),E3(N1,N2),F1,F2,A(N1,N1)
      DOUBLE PRECISION R1,R2,R3,R4,XN
      INTEGER AA(40),N(35)
      DIMENSION L(48),K(35),MT(35),R1(48),R2(48),R3(35),R4(35)
      INTEGER K0/' '/,K1/'VALU'/,K2/'ES'/,K3/'END'/,K4/'OGEN'/,K5/'OUS '
     1/, K6/'   L'/,K7/'AGGE'/, K8/'D EX'/,K9/'OGEN'/,K10/'OUS '/, K11/
     1'  EX'/,K12/'  LA'/,K13/'GGED'/,K14/' END'/,K15/'ACTU'/,K16/'AL A'
     1/,K17/'ND P'/,K18/'REDI'/,K19/'CTED'/,K20/' TIM'/,K21/'E PA'/,K22
     1/'THS '/,K23/'VALI'/,K24/'DATI'/,K25/'ON  '/,K26/'TURN'/,K27/'ING
     1'/, K28/'POIN'/,K29/'T ER'/,K30/'RORS'/,K31/'CHAN'/,K32/'GE S'/,K3
     13/'TATI'/,K34/'STIC'/,K35/'S   '/,K36/'INEQ'/,K37/'UALI'/,K38/'TY
     1P'/, K39/'REPO'/,K40/'RTIO'/,K41/'NS A'/,K42/'ND O'/,K43/'PT. '/,K
     144/'CORR'/,K45/'S'/
      COMMON/T1/N/T6/L/T7/MT/T8/K/T9/AA/T11/M3/T12/M2/T13/M1/T30/R1/T31/
     1R2/T32/R3/T3/IC/T50/R4
   78 DO 64 I=1,N1
      DO 94 J=1,2
   94 E1(J,I)=0.
      DO 64 J=1,5
   64 E3(I,J)=0.
      DO 95 I=1,N2
      DO 95 J=1,2
   95 E2(J,I)=0.
      F1=0.
      F2=0.
      IF(NN.EQ.1)GO TO 91
      IF(N(21).EQ.1)GO TO 3
      IF(NRT.EQ.1)GO TO 123
      IF(N(28).EQ.1)GO TO 122
```

```
      READ(5,1)(AA(I),I=1,40)
      WRITE(6,111)(AA(I),I=1,40)
      GO TO 123
  122 READ(5,1)(AA(I),I=1,20)
      WRITE(6,111)(AA(I),I=1,20)
  111 FORMAT(' ',20A4)
  123 N(21)=1
    1 FORMAT(20A4)
    3 N11=NT-1
      IF(N(25).EQ.1)N11=NT
C READ IN DATA AND COMPUTE INEQUALITY COEFFICIENTS
   91 M=0
      IF(NN.EQ.1)GO TO 99
      READ(10,93)M1
      IF(M1.EQ.0)GO TO 83
      READ(10,93)(L(JJ),JJ=1,M1)
   83 READ(10,93)M2
      IF(M2.EQ.0)GO TO 84
      READ(10,93)(MT(JJ),JJ=1,M2)
   84 READ(10,93)M3
      IF(M3.EQ.0)GO TO 99
      READ(10,93)(K(JJ),JJ=1,M3)
   93 FORMAT(26I3)
   99 IF(N(33).EQ.0.OR.ID.EQ.4)GO TO 199
      READ(9,AA)(E1(2,I),I=1,N1),(E2(2,I),I=1,N2)
      N(33)=0
  199 IF(ID.EQ.4)GO TO 69
      READ(9,AA)(E1(1,I),I=1,N1),(E2(1,I),I=1,N2)
      GO TO 65
   69 IF(M.EQ.0)READ(5,AA)(E1(2,I),I=1,N1),(E2(2,I),I=1,N2)
      IF(NN.EQ.0)READ(5,AA)(E1(1,I),I=1,N1),(E2(1,I),I=1,N2)
      IF(NN.EQ.0.AND.N(17).EQ.1)WRITE(8,10)(E1(1,I),I=1,N1),
```

```
     1(E2(1,MT(I)),I=1,M2),(E2(2,K(I)),I=1,M3)
      IF(NN.EQ.1)READ(8,10)(E1(1,I),I=1,N1),(E2(1,MT
     1(I)),I=1,M2),(E2(2,K(I)),I=1,M3)
 55   M=M+1
      IF(M.GT.1)READ(13,10)(E1(2,L(I)),I=1,M1),(E2(2,K(I)),I=1,M3)
      IF(M.GT.1)REWIND 13
      IF(N(28).EQ.0)GO TO 124
      IF(M.LT.N(29))GO TO 120
124   IF(N(12).NE.1)GO TO 2
      CALL PVR(E1,N1,N1,1,N1,K0,K0,K0,K14,K4,K5,K1,K2,K0,K0)
      CALL PVR(E1,N1,N1,2,N1,K0,K0,K0,K12,K13,K14,K9,K10,K1,K2)
      CALL PVR(E2,N1,N2,1,N2,K0,K0,K0,K11,K9,K10,K1,K2,K0,K0)
      CALL PVR(E2,N1,N2,2,N2,K0,K0,K0,K7,K8,K9,K10,K1,K2,K0)
      N(12)=0
  2   CALL MRPRD(D1,E1,N1,N1,2,1)
      CALL MRPRD(D2,E2,N1,N2,1,2)
      CALL MRPRD(D3,E2,N1,N2,2,3)
      DO 4 I=1,N1
  4   E0(I)=D0(I)+R1(I)+R2(I)+R3(I)
      GO TO 15
190   DO 14 KK=1,N1
 14   E0(KK)=A(3,KK)+R4(KK)*E0(KK)
      GO TO 191
 15   IF(N(15).NE.1.OR.NN.EQ.1)GO TO 8
      IF(M.EQ.1)CALL TITLE(K0,K0,K15,K16,K17,K18,K19,K20,K21,K22)
      WRITE(6,5)M
      WRITE(6,6)(E1(1,I),E0(I),I=1,N1)
  5   FORMAT(' ',I3,')')
  6   FORMAT(' ',10(1X,G12.5))
  8   IF(NN.EQ.1)GO TO 82
      IF(N(25).EQ.1)GO TO 103
      IF(N(22).EQ.1)GO TO 80
```

```
  191 WRITE(4,10)(E0(I),I=1,N1)
   82 IF(M.EQ.N(29).AND.N(28).EQ.1)GO TO 9
      IF(M.EQ.1)GO TO 9
      READ(3,10)(E3(I,1),I=1,N1)
      READ(3,10)(E3(I,2),I=1,N1)
      REWIND 3
    9 WRITE(3,10)(E1(1,I),I=1,N1)
      WRITE(3,10)(E0(I),I=1,N1)
      REWIND 3
  103 DO 11 I=1,N1
   11 E3(I,3)=E0(I)+E3(I,3)
      IF(N(25).NE.1.AND.N(22).NE.1)GO TO 30
      IF(N(22).EQ.1.AND.N(25).EQ.0)GO TO 192
      DO 104 I=1,N1
  104 E3(I,4)=E1(1,I)+E3(I,4)
   30 CONTINUE
      IF(N(27).EQ.1)GO TO 120
      WRITE(13,10)(E0(L(I)),I=1,M1),(E2(1,K(I)),I=1,M3)
      GO TO 121
  120 WRITE(13,10)(E1(1,L(I)),I=1,M1),(E2(1,K(I)),I=1,M3)
  121 REWIND 13
      IF(N(22).EQ.1.AND.N(25).EQ.0)GO TO 190
  192 IF(M.LT.N(29).AND.N(28).EQ.1)GO TO 99
      IF(N(25).EQ.1)GO TO 62
      IF(M.EQ.1)GO TO 99
      IF(M.EQ.N(29).AND.N(28).EQ.1)GO TO 99
      DO 16 I=1,N1
      IF(E3(I,2).EQ.0.0)E3(I,2)=.0001
      IF(E3(I,1).EQ.0.0)E3(I,1)=.0001
      E0(I)=(E0(I)-E3(I,2))/E3(I,2)
      E1(1,I)=(E1(1,I)-E3(I,1))/E3(I,1)
   16 CONTINUE
```

```
      IF(ID.EQ.4.AND.N(23).EQ.1)GO TO 17
      IF(NN.NE.1)GO TO 62
   17 CONTINUE
      DO 61 I=1,N1
   61 E0(I)=A(1,I)+A(2,I)*E0(I)
   62 WRITE(12,10)(E0(I),I=1,N1)
      WRITE(12,10)(F1(1,I),I=1,N1)
      IF(N(25).EQ.1)GO TO 100
   10 FORMAT(6E13.6)
      DO 21 I=1,N1
      E3(I,4)=((E0(I)-F1(1,I))**2)+E3(I,4)
   21 E3(I,5)=(E1(1,I)**2)+E3(I,5)
  100 IF(M.LT.NT)GO TO 99
      IF(N(25).EQ.1)GO TO 101
      IF(NN.EQ.0)REWIND 4
  101 REWIND 12
      REWIND 10
      REWIND 9
      IF(N(25).EQ.1)GO TO 102
      CALL TITLE(K0,K0,K0,K23,K24,K25,K0,K0,K0,K0)
      IF(N(23).EQ.1.AND.ID.EQ.4)WRITE(6,18)
   18 FORMAT(' ',56X,'...OPTIMALLY CORRECTED...'/)
      WRITE(6,22)
   22 FORMAT(' ',5X,'VARIABLE',3X,'ROOT MEAN SQUARE',5X,'INEQUALITY COEF
     1FICIENT',7X,'PRED. MEAN',6X,'PRED. STD. DEV.'/)
      IF(N(28).EQ.1)NT=NT-N(29)+1
      DO 23 I=1,N1
      E3(I,1)=0.
      E3(I,3)=E3(I,3)/NT
      E3(I,5)=DSQRT(E3(I,4)/E3(I,5))
      E3(I,4)=E3(I,4)/(NT-1)
      F1=E3(I,5)+F1
```

```
   23  CONTINUE
       WRITE(11,10)(E3(I,4),I=1,N1)
       DO 19 I=1,N1
       E3(I,4)=DSQRT(E3(I,4))
   19  F2=E3(I,4)+F2
       REWIND 11
       IF(NN.EQ.1)GO TO 81
       DO 24 I=1,NT
       READ(4,10)(E0(II),II=1,N1)
       DO 24 J=1,N1
   24  E3(J,1)=((E0(J)-E3(J,3))**2)+E3(J,1)
       REWIND 4
       DO 25 I=1,N1
   25  E3(I,1)=DSQRT(E3(I,1)/(NT-1))
   81  DO 26 I=1,N1
   26  WRITE(6,27)I,E3(I,4),E3(I,5),E3(I,3),E3(I,1)
   27  FORMAT(' ',5X,I3,5X,2F20.8,2F20.8)
       F1=F1/N1
       F2=F2/N1
       WRITE(6,28)F1,F2
   28  FORMAT(' ',/2X,'ALL VARIABLES',4X,2F20.8)
       IF(N(24).EQ.0)GO TO 96
C COUNT TURNING POINTS
       DO 29 I=1,N1
       E2(I,1)=0.
       E2(I,2)=0.
       F1(2,I)=0.
       DO 29 J=1,5
   29  E3(I,J)=0.
       IKK=0
   63  IKK=IKK+1
       READ(12,10)(E0(I),I=1,N1)
```

```
      READ(12,10)(E1(1,I),I=1,N1)
      DO 30 J=1,N1
      IF(IKK.EQ.1)GO TO 31
      IF(E1(1,J).GT.0..AND.E3(J,2).LE.0)GO TO 32
      IF(E1(1,J).LE.0..AND.E3(J,2).GT.0)GO TO 32
      GO TO 31
   32 E1(2,J)=E1(2,J)+1.
      IF(E0(J).GT.0..AND.E3(J,3).LE.0..AND.E1(1,J).GT.0..AND.E3(J,2).LE.
     10.)GO TO 34
      IF(E0(J).LE.0..AND.E3(J,3).GT.0..AND.E1(1,J).LE.0..AND.E3(J,2).GT.
     10.)GO TO 34
      GO TO 31
   34 E3(J,5)=E3(J,5)+1.
   31 IF(E1(1,J).GT.0.)E3(J,2)=1.
      IF(E1(1,J).LE.0.)E3(J,2)=0
      IF(E0(J).GT.0.)E3(J,3)=1.
      IF(E0(J).LE.0.)E3(J,3)=0.
      IF(E1(1,J).GT.0.AND.E0(J).LE.0.)E3(J,4)=E3(J,4)+1.
      IF(E1(1,J).LE.0.AND.E0(J).GT.0.)E3(J,4)=E3(J,4)+1.
      E2(J,1)=E1(1,J)+E2(J,1)
   30 E2(J,2)=E0(J)+E2(J,2)
      IF(IKK.LT.N11)GO TO 63
      REWIND 12
      CALL TITLE(K0,K0,K0,K26,K27,K28,K29,K30,K0,K0)
      WRITE(6,39)
      DO 68 I=1,N1
      IF(E1(2,I).EQ.0.)GO TO 73
      E3(I,2)=E3(I,5)/E1(2,I)
      GO TO 33
   73 E3(I,2)=1.0000
   33 E2(I,3)=E3(I,4)/(NT-1)
   68 WRITE(6,35)I,E3(I,4),E2(I,3),E1(2,I),E3(I,5),E3(I,2)
```

```
 35   FORMAT(' ',5X,I4,3X,F20.0,F20.4,2F20.0,F20.4)
 39   FORMAT(' ',3X,'VARIABLE',5X,'NO. DIRECTION ERRORS',5X,'PERCENTAGE
     1ERROR',5X,'NO. TURN PTS.',5X,'NO. CORR. PRED. PTS.',5X,'PERCENTAGE
     1 CORR.',/)
C COMPUTE MEAN, STD DEV, AND VAR
      IF(ID.EQ.4.AND.N(23).EQ.1)GO TO 7
      IF(ID.EQ.3.AND.N(23).EQ.1.AND.NN.EQ.1)GO TO 7
      DO 38 I=1,N1
      E3(I,2)=0.
      E3(I,3)=0.
      E3(I,5)=0.
      E3(I,1)=E2(I,1)/N11
 38   E3(I,4)=E2(I,2)/N11
      GO TO 105
102   IF(N(28).EQ.1)NT=NT-N(29)+1
      IF(N(28).EQ.1)N11=NT
      DO 106 I=1,N1
      E3(I,1)=E3(I,4)/NT
106   E3(I,4)=E3(I,3)/NT
      DO 107 I=1,N1
      E3(I,2)=0.
      E3(I,5)=0.
107   E3(I,3)=0.
105   IKK=0
 89   IKK=IKK+1
      READ(12,10)(E0(I),I=1,N1)
      READ(12,10)(E1(1,I),I=1,N1)
      DO 40 I=1,N1
      E3(I,2)=((E1(1,I)-E3(I,1))**2)+E3(I,2)
      E3(I,5)=((E0(I)-E3(I,4))**2)+E3(I,5)
 40   E3(I,3)=(E1(1,I)-E3(I,1))*(E0(I)-E3(I,4))+E3(I,3)
      IF(IKK.LT.N11)GO TO 89
```

```
      DO 41 I=1,N1
      E3(I,2)=E3(I,2)/(NT-1)
      E3(I,5)=E3(I,5)/(NT-1)
      E3(I,3)=E3(I,3)/(NT-1)
      E1(1,I)=DSQRT(DABS(E3(I,2)))
      E0(I)=DSQRT(DABS(E3(I,5)))
      XN=E0(I)*E1(1,I)
      IF(XN.EQ.0.)XN=.0001
   41 E3(I,3)=E3(I,3)/XN
      REWIND 12
      IF(N(25).EQ.1)GO TO 108
      CALL TITLE(K0,K0,K0,K31,K32,K33,K34,K35,K0,K0)
      WRITE(6,42)
   42 FORMAT(' ',3X,'VARIABLE',3(8X,'ACTUAL',8X,'PREDICTED'),8X,'CORRELA
     1TION',/21X,'MEAN',11X,'MEAN',2(9X,'STD. DEV.'),2(7X,'VARIANCE'),7X
     1,'COEFFICIENT'/)
      DO 43 I=1,N1
   43 WRITE(6,44)I,E3(I,1),E3(I,4),E1(1,I),E0(I),E3(I,2),E3(I,5),E3(I,3)
   44 FORMAT(' ',3X,I3,3X,7F16.6)
C COMPUTE INEQUALITY PROPORTIONS
      READ(11,10)(E2(I,1),I=1,N1)
      REWIND 11
  108 DO 45 I=1,N1
      IF(N(25).EQ.1)GO TO 109
      E2(I,2)=((E3(I,4)-E3(I,1))**2)/E2(I,1)
      E3(I,2)=((E0(I)-E3(I,3)*E1(1,I))**2)/E2(I,1)
C     E3(I,5)=((1.-(E3(I,3)**2))*(E1(1,I)**2))/E2(I,1)
      E3(I,5)=1.-E2(I,2)-E3(I,2)
  109 IF(E0(I).EQ.0.)E0(I)=.0001
      A(2,I)=E3(I,3)*E1(1,I)/E0(I)
   45 A(1,I)=E3(I,1)-A(2,I)*E3(I,4)
      IF(N(25).EQ.1)GO TO 96
```

```
      CALL TITLE(K36,K37,K38,K39,K40,K41,K42,K43,K44,K45)
      WRITE(6,47)
      DO 46 I=1,N1
   46 WRITE(6,44)I,E2(I,2),E3(I,2),E3(I,5),A(1,I),A(2,I)
   47 FORMAT(' ',3X,'VARIABLE',9X,'BIAS',9X,'REGRESSION',6X,'DISTURBANCE
     1', 6X,'INTERCEPT',8X,'SLOPE',/11X,3(6X,'PROPORTION')/)
    7 IF(ID.EQ.4.AND.N(17).EQ.1)REWIND 8
      IF(NN.EQ.1)GO TO 96
      IF(ID.EQ.4.AND.N(25).EQ.1)GO TO 96
      NN=1
      IF(ID.EQ.3.AND.N(16).EQ.1)GO TO 78
      IF(ID.EQ.4.AND.N(17).EQ.1)GO TO 78
   96 RETURN
      END
C
C SUBROUTINE REVISE READS IN OR CALCULATES OPTIMAL LINEAR CORRECTIONS FO
C R LEVELS OF PREDICTED VARIABLES
C A(3,I) IS INTERCEPT ..........R4(I) IS SLOPE.......
      SUBROUTINE REVISE(A,N,D0,D1,D2,D3,E0,E1,E2,E3,N2,NT,NRT)
      REAL*8 A(N,N),D0(N),D1(N,N),D2(N,N2),D3(N,N2),E0(N),E1(N,N),E2(N,N
     12),E3(N,N2)
      DOUBLE PRECISION R4
      DIMENSION R4(35)
      INTEGER II(35),K1/'    '/,K2/' LIN'/,K3/'EAR '/,K4/'REVI'/,K5/'SION'/
     1,K6/'S'/
      COMMON/T1/II/T50/R4
      IF(II(25).EQ.1)GO TO 22
      IF(II(10)-1)1,2,3
    1 DO 12 I=1,N
   12 READ(5,13)A(3,I),R4(I)
   13 FORMAT(2F10.0)
      GO TO 4
```

```
 2  DO 14 I=1,N
14  READ(5,15)A(3,I),R4(I)
15  FORMAT(20X,2F10.0)
    GO TO 4
 3  DO 16 I=1,N
16  READ(5,17)A(3,I),R4(I)
17  FORMAT(40X,2F10.0)
 4  CALL TITLE(K1,K1,K1,K2,K3,K4,K5,K6,K1,K1)
    WRITE(6,33)
33  FORMAT(' ',55X,'...SUBMITTED...'/)
    DO 20 I=1,N
20  WRITE(6,21)A(3,I),R4(I)
21  FORMAT(' ',F20.6,5X,F20.6)
    GO TO 24
22  II(22)=0
    NLL=0
41  NQ=II(15)
    II(15)=0
    NN=0
    CALL VALID(D0,D1,D2,D3,N,N2,E0,E1,E2,E3,NN,NT,A,NRT)
    CALL TITLE(K1,K1,K1,K2,K3,K4,K5,K6,K1,K1)
    WRITE(6,30)
    DO 23 I=1,N
    A(3,I)=A(1,I)
    R4(I)=A(2,I)
23  WRITE(6,21)A(3,I),R4(I)
30  FORMAT(' ',55X,'...CALCULATED...'/)
    II(22)=1
    II(15)=NQ
    II(25)=0
    II(33)=1
24  RETURN
```

```
      END
C
C SUBROUTINE RM READS IN A MATRIX IN STANDARD FORM
      SUBROUTINE RM(A,N,M)
      REAL*8 A(N,M),EIJ
      INTEGER II(35)
      COMMON/T1/II
      DO 4 K=1,N
      DO 4 L=1,M
    4 A(K,L)=0.
  3   IF(II(10)-1)10,11,12
  10  READ(5,1)I,J,EIJ
      GO TO 5
  11  READ(5,7)I,J,EIJ
   7  FORMAT(2I4,10X,F10.0)
      GO TO 5
  12  READ(5,8)I,J,EIJ
   8  FORMAT(2I4,20X,F10.0)
   5  IF(I.EQ.0)GO TO 2
   1  FORMAT(2I4,F10.0)
      A(I,J)=EIJ
      GO TO 3
   2  RETURN
      END
C
C SUBROUTINE RV READS IN A VECTOR IN STANDARD FORM
      SUBROUTINE RV(A,N)
      REAL*8 A(N),EI
      INTEGER II(35)
      COMMON/T1/II
      DO 4 J=1,N
    4 A(J)=0.
```

```
    3   IF(II(10)-1)10,11,12
   10   READ(5,1)I,EI
        GO TO 5
   11   READ(5,7)I,EI
    7   FORMAT(I4,10X,F10.0)
        GO TO 5
   12   READ(5,8)I,EI
    8   FORMAT(I4,20X,F10.0)
    5   IF(I.EQ.0)GO TO 2
    1   FORMAT(I4,F10.0)
        A(I)=EI
        GO TO 3
    2   RETURN
        END
C
C SUBROUTINE PM PRINTS A MATRIX
        SUBROUTINE PM(A,N,M,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10)
        REAL*8 A(N,M)
        CALL TITLE(I1,I2,I3,I4,I5,I6,I7,I8,I9,I10)
        DO 2 I=1,N
        WRITE(6,4)I
    2   WRITE(6,3)(A(I,J),J=1,M)
    3   FORMAT(' ',10(1X,G12.5))
    4   FORMAT(' ',I5,')')
        RETURN
        END
C
C SUBROUTINE MVPRD MULTIPLIES MATRIX A BY VECTOR B
        SUBROUTINE MVPRD(A,B,C,N,M)
        REAL*8 A(N,M),B(M),C(N)
        DO 1 J=1,N
    1   C(J)=0.
```

```
      DO 2 I=1,N
      DO 2 J=1,M
    2 C(I)=A(I,J)*B(J)+C(I)
      RETURN
      END
C
C SUBROUTINE PV PRINTS VECTOR A
      SUBROUTINE PV(A,N,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10)
      REAL*8 A(N)
      CALL TITLE(I1,I2,I3,I4,I5,I6,I7,I8,I9,I10)
    1 WRITE(6,4)(A(I),I=1,N)
    4 FORMAT(' ',10(1X,G12.5))
      RETURN
      END
C
C SUBROUTINE MSUM ADDS MATRIX A TO MATRIX B AND RETURNS SUM AS MATRIX A
      SUBROUTINE MSUM(A,B,N,M)
      REAL*8 A(N,M),B(N,M)
      DO 1 J=1,M
      DO 1 I=1,N
    1 A(I,J)=A(I,J)+B(I,J)
      RETURN
      END
C
C SUBROUTINE SQPRD MULTIPLIES TWO SQUARE MATRICES AND RETURNS PRODUCT AS
C MATRIX B
      SUBROUTINE SQPRD(A,B,C,N)
      REAL*8 A(N,N),B(N,N),C(N)
      I=0
    5 I=I+1
      DO 1 J=1,N
      C(J)=0.
```

```
      DO 1 JJ=1,N
    1 C(J)=A(I,JJ)*B(JJ,J)+C(J)
      WRITE(4,7)(C(J),J=1,N)
    7 FORMAT(6E13.6)
      IF(I.EQ.N)GO TO 8
      GO TO 5
    8 REWIND 4
      DO 9 I=1,N
    9 READ(4,7)(B(I,J),J=1,N)
      REWIND 4
      RETURN
      END
C
C SUBROUTINE MSUB SUBTRACTS MATRIX B FROM MATRIX A AND RETURNS MATRIX
C A AS DIFFERENCE
      SUBROUTINE MSUB(A,B,N,M)
      REAL*8 A(N,M),B(N,M)
      DO 1 I=1,N
      DO 1 J=1,M
    1 A(I,J)=A(I,J)-B(I,J)
      RETURN
      END
C SUBROUTINE PVR PRINTS ITH ROW OF MATRIX A
C
      SUBROUTINE PVR(A,N,M,I,J,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10)
      REAL*8 A(N,M)
      CALL TITLE(I1,I2,I3,I4,I5,I6,I7,I8,I9,I10)
      WRITE(6,1)(A(I,M),M=1,J)
    1 FORMAT(' ',10(1X,G12.5))
      RETURN
      END
C SUBROUTINE MRPRD MULTIPLIES TWO ROWS FROM DIFFERENT MATRICES
```

```
      SUBROUTINE MRPRD(A,B,N,M,K,KK)
      REAL*8 A(N,M),B(N,M)
      DIMENSION R1(48),R2(48),R3(35)
      DOUBLE PRECISION R1,R2,R3
      COMMON/T30/R1/T31/R2/T32/R3
      IF(KK-2)7,8,9
    7 DO 10 I=1,N
      R1(I)=0.
      DO 10 JJ=1,M
   10 R1(I)=A(I,JJ)*B(K,JJ)+R1(I)
      GO TO 12
    8 DO 13 I=1,N
      R2(I)=0.
      DO 13 JJ=1,M
   13 R2(I)=A(I,JJ)*B(K,JJ)+R2(I)
      GO TO 12
    9 DO 14 I=1,N
      R3(I)=0.
      DO 14 JJ=1,M
   14 R3(I)=A(I,JJ)*B(K,JJ)+R3(I)
   12 RETURN
      END
C
C SUBROUTINE ATEIG COMPUTES EIGENVALUES OF MATRIX A
      SUBROUTINE ATEIG(M,A,RR,RI,IANA,IA)
      DIMENSION A(1),RR(1),RI(1),PRR(2),PRI(2),IANA(1)
      DOUBLE PRECISION A,RR,RI,PRR,PRI,T,U,V,E6,E7,E10,RMOD,EPS,R,S,PAN,
     1PAN1,D,G1,G2,G3,CAP,PSI1,PSI2,ALPHA,ETA
      INTEGER P,P1,Q
      E7=1.0E-8
      E6=1.0E-6
      E10=1.0E-10
```

```
      DELTA=0.5
      MAXIT=30
      N=M
   20 N1=N-1
      IN=N1*IA
      NN=IN+N
      IF(N1) 30,1300,30
   30 NP=N+1
      IT=0
      DO 40 I=1,2
      PRR(I)=0.0
   40 PRI(I)=0.0
      PAN=0.0
      PAN1=0.0
      R=0.0
      S=0.0
      N2=N1-1
      IN1=IN-IA
      NN1=IN1+N
      N1N=IN+N1
      N1N1=IN1+N1
   60 T=A(N1N1)-A(NN)
      U=T*T
      V=4.0*A(N1N)*A(NN1)
      IF(DABS(V)-U*E7) 100,100,65
   65 T=U+V
C CHANGE DMAX1 TO AMAX1 FOR SINGLE PRECISION
      IF(DABS(T)-DMAX1(U,DABS(V))*E6) 67,67,68
   67 T=0.0
   68 U=(A(N1N1)+A(NN))/2.0
      V=DSQRT(DABS(T))/2.0
      IF(T)140,70,70
```

```
70  IF(U) 80,75,75
75  RR(N1)=U+V
    RR(N)=U-V
    GO TO 130
80  RR(N1)=U-V
    RR(N)=U+V
    GO TO 130
100 IF(T)120,110,110
110 RR(N1)=A(N1N1)
    RR(N)=A(NN)
    GO TO 130
120 RR(N1)=A(NN)
    RR(N)=A(N1N1)
130 RI(N)=0.0
    RI(N1)=0.0
    GO TO 160
140 RR(N1)=U
    RR(N)=U
    RI(N1)=V
    RI(N)=-V
160 IF(N2)1280,1280,180
180 N1N2=N1N1-IA
    RMOD=RR(N1)*RR(N1)+RI(N1)*RI(N1)
    EPS=E10*DSQRT(RMOD)
    IF(DABS(A(N1N2))-EPS)1280,1280,240
240 IF(DABS(A(NN1))-E10*DABS(A(NN))) 1300,1300,250
250 IF(DABS(PAN1-A(N1N2))-DABS(A(N1N2))*E6) 1240,1240,260
260 IF(DABS(PAN-A(NN1))-DABS(A(NN1))*E6)1240,1240,300
300 IF(IT-MAXIT) 320,1240,1240
320 J=1
    DO 360 I=1,2
    K=NP-I
```

```
      IF(DABS(RR(K)-PRR(I))+DABS(RI(K)-PRI(I))-DELTA*(DABS(RR(K))
     1    +DABS(RI(K)))) 340,360,360
  340 J=J+I
  360 CONTINUE
      GO TO (440,460,460,480),J
  440 R=0.0
      S=0.0
      GO TO 500
  460 J=N+2-J
      R=RR(J)*RR(J)
      S=RR(J)+RR(J)
      GO TO 500
  480 R=RR(N)*RR(N1)-RI(N)*RI(N1)
      S=RR(N)+RR(N1)
  500 PAN=A(NN1)
      PAN1=A(N1N2)
      DO 520 I=1,2
      K=NP-I
      PRR(I)=RR(K)
  520 PRI(I)=RI(K)
      P=N2
      IF (N-3)600,600,525
  525 IPI=N1N2
      DO 580 J=2,N2
      IPI=IPI-IA-1
      IF(DABS(A(IPI))-EPS) 600,600,530
  530 IPIP=IPI+IA
      IPIP2=IPIP+IA
      D=A(IPIP)*(A(IPIP)-S)+A(IPIP2)*A(IPIP+1)+R
      IF(D)540,360,540
  540 IF(DABS(A(IPI)*A(IPIP+1))*(DABS(A(IPIP)+A(IPIP2+1)-S)+DABS(A(IPIP2
     1+2) )) -DABS(D)*EPS) 620,620,560
```

```
560 P=N1-J
580 CONTINUE
600 Q=P
    GO TO 680
620 P1=P-1
    Q=P1
    IF (P1-1) 680,680,650
650 DO 660 I=2, P1
    IPI=IPI-IA-1
    IF(DABS(A(IPI))-EPS)680,680,660
660 Q=Q-1
680 II=(P-1)*IA+P
    DO 1220 I=P,N1
    II1=II-IA
    IIP=II+IA
    IF(I-P)720,700,720
700 IPI=II+1
    IPIP=IIP+1
    G1=A(II)*(A(II)-S)+A(IIP)*A(IPI)+R
    G2=A(IPI)*(A(IPIP)+A(II)-S)
    G3=A(IPI)*A(IPIP+1)
    A(IPI+1)=0.0
    GO TO 780
720 G1=A(II1)
    G2=A(II1+1)
    IF(I-N2)740,740,760
740 G3=A(II1+2)
    GO TO 780
760 G3=0.0
780 IF(G1.GT.-E10.AND.G1.LT.E10)G1=0.0
    IF(G2.GT.-E10.AND.G2.LT.E10)G2=0.0
    IF(G3.GT.-E10.AND.G3.LT.E10)G3=0.0
```

```
      CAP=DSQRT(G1*G1+G2*G2+G3*G3)
      IF(CAP)800,860,800
  800 IF(G1)820,840,840
  820 CAP=-CAP
  840 T=G1+CAP
      PSI1=G2/T
      PSI2=G3/T
      ALPHA=2.0/(1.0+PSI1*PSI1+PSI2*PSI2)
      GO TO 880
  860 ALPHA=2.0
      PSI1=0.0
      PSI2=0.0
  880 IF(I-Q)900,960,900
  900 IF(I-P)920,940,920
  920 A(II1)=-CAP
      GO TO 960
  940 A(II1)=-A(II1)
  960 IJ=II
      DO 1040 J=I,N
      T=PSI1*A(IJ+1)
      IF(I-N1)980,1000,1000
  980 IP2J=IJ+2
      T=T+PSI2*A(IP2J)
 1000 ETA=ALPHA*(T+A(IJ))
      A(IJ)=A(IJ)-ETA
      A(IJ+1)=A(IJ+1)-PSI1*ETA
      IF(I-N1)1020,1040,1040
 1020 A(IP2J)=A(IP2J)-PSI2*ETA
 1040 IJ=IJ+IA
      IF(I-N1)1080,1060,1060
 1060 K=N
      GO TO 1100
```

```
1080 K=I+2
1100 IP=IIP-I
     DO 1180 J=Q,K
     JIP=IP+J
     JI=JIP-IA
     T=PSI1*A(JIP)
     IF(I-N1)1120,1140,1140
1120 JIP2=JIP+IA
     T=T+PSI2*A(JIP2)
1140 ETA=ALPHA*(T+A(JI))
     A(JI)=A(JI)-ETA
     A(JIP)=A(JIP)-ETA*PSI1
     IF(I-N1)1160,1180,1180
1160 A(JIP2)=A(JIP2)-ETA*PSI2
1180 CONTINUE
     IF(I-N2)1200,1220,1220
1200 JI=II+3
     JIP=JI+IA
     JIP2=JIP+IA
     ETA=ALPHA*PSI2*A(JIP2)
     A(JI)=-ETA
     A(JIP)=-ETA*PSI1
     A(JIP2)=A(JIP2)-ETA*PSI2
1220 II=IIP+1
     IT=IT+1
     GO TO 60
1240 IF(DABS(A(NN1))-DABS(A(N1N2))) 1300,1280,1280
1280 IANA(N)=0
     IANA(N1)=2
     N=N2
     IF(N2)1400,1400,20
1300 RR(N)=A(NN)
```

```
      RI(N)=0.0
      IANA(N)=1
      IF(N1)1400,1400,1320
 1320 N=N1
      GO TO 20
 1400 RETURN
      END
C
C SUBROUTINE HSB6 PUTS MATRIX A INTO UPPER TRIANGULAR FORM
      SUBROUTINE HSB6(N,A,IA)
      DIMENSION A(1)
      DOUBLE PRECISION S,A,PIV,T
      E10=1.0E-10
      L=N
      NIA=L*IA
      LIA=NIA-IA
   20 IF(L-3) 360,40,40
   40 LIA=LIA-IA
      L1=L-1
      L2=L1-1
      ISUB=LIA+L
      IPIV=ISUB-IA
      PIV=DABS(A(IPIV))
      IF(L-3) 90,90,50
   50 M=IPIV-IA
      DO 80 I=L,M,IA
      T=DABS(A(I))
      IF(T-PIV) 80,80,60
   60 IPIV=I
      PIV=T
   80 CONTINUE
   90 IF(PIV) 100,320,100
```

```
100 IF(PIV-DABS(A(ISUB))) 180,180,120
120 M=IPIV-L
    DO 140 I=1,L
    J=M+I
    T=A(J)
    K=LIA+I
    A(J)=A(K)
140 A(K)=T
    M=L2-M/IA
    DO 160 I=L1,NIA,IA
    T=A(I)
    J=I-M
    A(I)=A(J)
160 A(J)=T
180 DO 200 I=L,LIA,IA
200 A(I)=A(I)/A(ISUB)
    J=-IA
    DO 240 I=1,L2
    J=J+IA
    LJ=L+J
    DO 220 K=1,L1
    KJ=K+J
    KL=K+LIA
220 A(KJ)=A(KJ)-A(LJ)*A(KL)
240 CONTINUE
    K=-IA
    DO 300 I=1,N
    K=K+IA
    LK=K+L1
    S=A(LK)
    LJ=L-IA
    DO 280 J=1,L2
```

```
      JK=K+J
      LJ=LJ+IA
      IF(DABS(A(LJ)).LT.E10)A(LJ)=0.0
      IF(DABS(A(JK)).LT.E10)A(JK)=0.0
  280 S=S+A(LJ)*A(JK)*1.000
  300 A(LK)=S
      DO 310 I=L,LIA,IA
  310 A(I)=0.0
  320 L=L1
      GO TO 20
  360 RETURN
      END
C
C SUBROUTINE MINV CALCULATES INVERSE OF MATRIX A
      SUBROUTINE MINV(A,N,D,L,M)
      DIMENSION A(1)
      DOUBLE PRECISION A,D,BIGA,HOLD
      INTEGER L(N),M(N)
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
   10 IF(DABS(BIGA)-DABS(A(IJ)))15,20,20
   15 BIGA=A(IJ)
```

```
      L(K)=I
      M(K)=J
   20 CONTINUE
      J=L(K)
      IF(J-K) 35,35,25
   25 KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
   30 A(JI) =HOLD
   35 I=M(K)
      IF(I-K) 45,45,38
   38 JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
   40 A(JI) =HOLD
   45 IF(BIGA) 48,46,48
   46 D=0.0
      RETURN
   48 DO 55 I=1,N
      IF(I-K) 50,55,50
   50 IK=NK+I
      A(IK)=A(IK)/(-BIGA)
   55 CONTINUE
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
```

```
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF(I-K) 60,65,60
   60 IF(J-K) 62,65,62
   62 KJ=IJ-I+K
      A(IJ)=HOLD*A(KJ)+A(IJ)
   65 CONTINUE
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K) 70,75,70
   70 A(KJ)=A(KJ)/BIGA
   75 CONTINUE
      D=D*BIGA
      A(KK)=1.0/BIGA
   80 CONTINUE
      K=N
  100 K=(K-1)
      IF(K) 150,150,105
  105 I=L(K)
      IF(I-K) 120,120,108
  108 JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JR+J
      A(JK)=-A(JI)
  110 A(JI) =HOLD
  120 J=M(K)
      IF(J-K) 100,100,125
```

```
  125 KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
  130 A(JI) =HOLD
      GO TO 100
  150 RETURN
      END
C
C SUBROUTINE GMPRD MULTIPLIES MATRIX A BY MATRIX B AND RETURNS MATRI
C R AS PRODUCT
      SUBROUTINE GMPRD(A,B,R,N,M,L)
      REAL*8 A(N,M),B(M,L),R(N,L)
      DO 1 I=1,N
      DO 1 J=1,L
      R(I,J)=0.
      DO 1 JJ=1,M
    1 R(I,J)=A(I,JJ)*B(JJ,J)+R(I,J)
      RETURN
      END
C
C SUBROUTINE COUNT COUNTS THE NUMBER OF NONZERO COLUMNS IN A MATRIX AND
C RECORDS THE COLUMN ID OF EACH NONZERO COLUMN ON UNIT 10.
      SUBROUTINE COUNT(A,N,M)
      DIMENSION L(40),K(35)
      REAL*8 A(N,M)
      COMMON/T6/L/T7/K
      NN=0
      DO 2 I=1,M
    2 L(I)=0
```

```
      DO 3 I=1,N
      DO 3 J=1,M
      IF(L(J).GE.1)GO TO 3
      IF(A(I,J).NE.0.)L(J)=J
    3 CONTINUE
      DO 4 J=1,M
      IF(L(J).GT.0)GO TO 5
      GO TO 4
    5 NN=NN+1
      K(NN)=L(J)
    4 CONTINUE
      WRITE(10,7)NN
      IF(NN.EQ.0)GO TO 8
      WRITE(10,7)(K(J),J=1,NN)
    7 FORMAT(26I3)
    8 RETURN
      END
C
C SIMULT GENERATES TIME PATHS, MEANS, STD DEVS, AND VARIANCES FOR DISCRE
C TE SIMULATIONS
      SUBROUTINE SIMULT(D0,D1,D2,D3,E0,E1,E2,E3,N1,N2,NT,A)
      REAL*8 D0(N1),D1(N1,N1),D2(N1,N2),D3(N1,N2),E0(N1),E1(N1,N1),E2(N1
     1,N2),E3(N1,N2),A(N1,N1)
      DOUBLE PRECISION R1,R2,R3,R4
      DIMENSION L(48),M(35),K(35),AA(40),K1(48),K2(48),R1(48),R2(48),R3(
     135),K3(35),R4(35)
      INTEGER L1/'SYST'/,L2/'EM S'/,L3/'IMUL'/,L4/'ATIO'/,L5/'N'/,L6/' '
     1/,N(35),L7/'TIME'/,L8/' PAT'/,L9/'HS'/
      COMMON/T6/L/T7/M/T8/K/T9/AA/T1/N/T11/M3/T12/M2/T13/M1/T40/K1/T41/K
     12/T30/R1/T31/R2/T32/R3/T50/R4
      NN=0
      IF(N(28).EQ.1)NT=NT-N(29)+1
```

```
      IF(N(30).EQ.1)NN=1
      NX=0
   43 READ(5,61)MC
   61 FORMAT(I3)
      NX=NX+1
      CALL TITLE(L6,L6,L6,L1,L2,L3,L4,L5,L6,L6)
      DO 1 I=1,MC
      READ(5,62)K1(I),K2(I),(A(J,I),J=1,2),K3(I)
    1 WRITE(6,100)K1(I),K2(I),(A(J,I),J=1,2),K3(I)
  100 FORMAT(' ',2I4,2F20.6,I4)
   62 FORMAT(2I4,2F12.0,I4)
      DO 3 J=1,N1
      DO 4 I=1,N1
    4 E1(J,I)=0.
      DO 3 I=1,N2
      E3(J,I)=0.
    3 E2(J,I)=0.
      IF(N(19).EQ.1)CALL TITLE(L6,L6,L6,L6,L7,L8,L9,L6,L6,L6)
      MM=0
      IF(N(3).EQ.1.OR.N(4).EQ.1)GO TO 2
      IF(N(21).EQ.1)GO TO 2
      IF(N(26).EQ.1)GO TO 95
      READ(5,44)(AA(I),I=1,40)
      GO TO 96
   95 READ(5,44)(AA(I),I=1,20)
   96 N(21)=1
   44 FORMAT(20A4)
      READ(10,93)M1
      IF(M1.EQ.0)GO TO 83
      READ(10,93)(L(J),J=1,M1)
   83 READ(10,93)M2
      IF(M2.EQ.0)GO TO 84
```

```
      READ(10,93)(M(J),J=1,M2)
   84 READ(10,93)M3
      IF(M3.EQ.0)GO TO 2
      READ(10,93)(K(J),J=1,M3)
      REWIND 10
    2 IF(MM.EQ.0)READ(9,AA)(E1(2,I),I=1,N1),(E2(2,I),I=1,N2)
      READ(9,AA)(E1(1,I),I=1,N1),(E2(1,I),I=1,N2)
    7 MM=MM+1
      IF(MM.GT.1)READ(13,10)(E1(2,L(I)),I=1,M1),(E2(2,K(I)),I=1,M3)
      IF(MM.GT.1)REWIND 13
      IF(N(28).EQ.0)GO TO 94
      IF(MM.LT.N(29))GO TO 66
C ALTER EXOGENOUS VARIABLES BY LINEAR TRANSFORM
   94 DO 8 I=1,MC
      IF(K2(I).EQ.1)GO TO 9
      E2(1,K1(I))=A(1,I)+A(2,I)*E2(1,K3(I))
      GO TO 8
    9 E2(1,K1(I))=A(1,I)+A(2,I)*E1(2,K3(I))
    8 CONTINUE
C COMPUTE MEANS, STD DEVS, AND VARIANCES
      CALL MRPRD(D1,E1,N1,N1,2,1)
      CALL MRPRD(D2,E2,N1,N2,1,2)
      CALL MRPRD(D3,E2,N1,N2,2,3)
      DO 11 I=1,N1
   11 E0(I)=D0(I)+R1(I)+R2(I)+R3(I)
      IF(N(27).EQ.1)GO TO 66
      WRITE(13,10)(E0(L(I)),I=1,M1),(E2(1,K(I)),I=1,M3)
      GO TO 67
   66 WRITE(13,10)(E1(1,L(I)),I=1,M1),(E2(1,K(I)),I=1,M3)
   67 REWIND 13
      IF(N(22).EQ.0)GO TO 102
      DO 101 I=1,N1
```

```
101   E0(I)=A(3,I)+R4(I)*E0(I)
102   CONTINUE
      DO 103 I=1,N1
103   E3(I,2)=E0(I)+E3(I,2)
      IF(MM.LT.N(29).AND.N(28).EQ.1)GO TO 2
      IF(NN.NE.0)GO TO 46
      DO 47 I=1,N1
 47   E3(I,1)=E1(1,I)+E3(I,1)
      WRITE(12,10)(E1(1,I),I=1,N1)
 46   IF(N(19).NE.1)GO TO 48
      WRITE(6,39)MM
      WRITE(6,38)(E0(I),I=1,N1)
 48   WRITE(11,10)(E0(I),I=1,N1)
      IF(MM.LT.N(13))GO TO 2
      REWIND 9
      REWIND 11
      REWIND 12
      DO 20 I=1,N1
      E1(3,I)=0.
      E3(I,2)=E3(I,2)/NT
      IF(NN.NE.0)GO TO 20
      R1(I)=0.
      E3(I,1)=E3(I,1)/NT
 20   CONTINUE
      NP=N(13)
      IF(N(28).EQ.1)NP=NT
      DO 21 II=1,NP
      READ(11,10)(E0(I),I=1,N1)
      DO 56 I=1,N1
 56   E1(3,I)=((E0(I)-E3(I,2))**2)+E1(3,I)
      IF(NN.NE.0)GO TO 21
      READ(12,10)(E1(1,I),I=1,N1)
```

```
      DO 57 I=1,N1
   57 R1(I)=((E1(1,I)-E3(1,1))**2)+R1(I)
   21 CONTINUE
      DO 22 I=1,N1
      E1(3,I)=E1(3,I)/(NT-1)
      R3(I)=DSQRT(E1(3,I))
      IF(NN.NE.0)GO TO 22
      R1(I)=R1(I)/(NT-1)
      R2(I)=DSQRT(R1(I))
   22 CONTINUE
      CALL TITLE(L6,L6,L6,L1,L2,L3,L4,L5,L6,L6)
      WRITE(6,30)
   30 FORMAT(' ',1X,'VARIABLE',3(6X,'ACTUAL',12X,'PREDICTED',6X)/,11X,2(
     17X,'MEAN',7X),2(5X,'STD. DEV.',5X),2(5X,'VARIANCE',5X)/)
      DO 31 I=1,N1
   31 WRITE(6,40)I,E3(I,1),E3(I,2),R2(I),R3(I),R1(I),E1(3,I)
   10 FORMAT(6F13.6)
   38 FORMAT(' ',10(1X,G12.5))
   39 FORMAT(' ',I3,')')
   40 FORMAT(' ',I3,6G20.6)
   93 FORMAT(26I3)
      REWIND 11
      REWIND 12
      NN=1
      IF(NX.LT.N(16))GO TO 43
      RETURN
      END
C
C SUBROUTINE CNTRL SETS UP CONTROL PROBLEM
      SUBROUTINE CNTRL(D0,D1,D2,D3,E0,E1,E2,E3,N1,N2,A)
      REAL*8 D0(N1),D1(N1,N1),D2(N1,N2),D3(N1,N2),E0(N1),E1(N1,N1),E2(N1
     1,N2),E3(N1,N2),A(N1,N1)
```

```
      DOUBLE PRECISION K,H,C,CT,W2,W3,A1,W4,G,AT,W6,W7
      DIMENSION K(48,48),H(48,48), C(48,4),CT(4,48),W2(4,48),W3(4,4),A1(
     148,48),W4(4,48),G(4,48),AT(48,48),W6(48,48), W7(48,48)
      COMMON/T3/ID/T90/K
      ID=6
      CALL BU(E0,E1,E2,E3,D0,D1,D2,D3,N1,N2,M1,M2,M3,M,NK,A)
      CALL TRANS(A1,M,C,NK,E1,E3,N2,A,N1)
      CALL ORDER(M1,M2,M3,N1,NK)
      CALL CHOW(E2,E3,D2,D3,A,D0,M,NK,K,H,C,CT,W2,W3,A1,W4,G,AT,W6,W7,N1
     1,E0,M1)
      RETURN
      END
C
C SUBROUTINE BU CALCULATES B VALUES FOR CONTROL PROBLEM
      SUBROUTINE BU(E0,E1,E2,E3,D0,D1,D2,D3,N1,N2,M1,M2,M3,M,NK,A)
      REAL*8 D0(N1),D1(N1,N1),D2(N1,N2),D3(N1,N2),E0(N1),E1(N1,N1),E2(N1
     1,N2),E3(N1,N2),A(N1,N1)
      DOUBLE PRECISION R1,R2,R3
      INTEGER II(35),AA(40),I1/'    '/,I2/' B  '/,I3/' U  '/,I4/'VECT'/,
     1I5/'OR  '/,I5/' INP'/,I7/'UT  '/,I8/' PRO'/,I9/'GRAM'/
      DIMENSION K1(48),K2(48),L(48),N(35),M(35),R1(48),R2(48),R3(35)
      COMMON/T1/II/T9/AA/T40/K1/T41/K2/T6/L/T7/K/T5/M/T30/R1/T31/R2/T32/
     1R3
C READ IN COL IDS OF CNTRL VARS; NK=NO CNTRL VARS....NL=NO LAGGED CNTRL
      IF(II(3)+II(4)+II(5).GT.0)GO TO 82
   83 FORMAT(20A4)
      IF(II(26).EQ.1)GO TO 81
      READ(5,83)(AA(I),I=1,40)
      GO TO 82
   81 READ(5,83)(AA(I),I=1,20)
   82 N1=II(13)
      DO 2 I=1,M1
```

```
      DO 3  J=1,N1
      A(I,J)=0.
    3 E1(I,J)=0.
      DO 2 J=1,N2
      E2(I,J)=0.
    2 E3(I,J)=0.
C READ IN NO CNTRL VARS AND CNTRL VAR IDS
      READ(5,1)(K1(I),I=1,26)
      READ(5,1)(K2(I),I=1,26)
      NK=K1(1)
      NL=K2(1)
      NP=NK+1
      NLL=NL+1
      CALL TITLE(I1,I1,I1,I8,I9,I6,I7,I1,I1,I1)
      WRITE(6,99)(K1(I),I=1,NP)
      WRITE(6,89)(K2(I),I=1,NLL)
   99 FORMAT(' ',/2X,'NO CURRENT CONTROL VARS:',I3,10X,'IDS:',25I3)
   89 FORMAT(' ',/2X,'NO LAGGED CONTROL VARS:',I4,10X,'IDS:',25I3)
    1 FORMAT(26I3)
      READ(10,1)M1
      IF(M1.EQ.0)GO TO 13
      READ(10,1)(L(J),J=1,M1)
   13 READ(10,1)M2
      IF(M2.EQ.0)GO TO 4
      READ(10,1)(K(J),J=1,M2)
    4 READ(10,1)M3
      IF(M3.EQ.0)GO TO 53
      READ(10,1)(N(J),J=1,M3)
C SET CNTRL PARMS IN D2, D3 EQUAL TO ZERO; MAKE A, E3 MATRICES OF CNTRL
   53 LL=0
      KK=0
      DO 6 J=1,NK
```

```
      KK=KK+1
      DO 6 I=1,N1
      A(I,KK)=D2(I,K1(J+1))
    6 D2(I,K1(J+1))=0.
      IF(NL.EQ.0)GO TO 39
      DO 31 J=1,NL
      LL=LL+1
      DO 31 I=1,N1
      E3(I,LL)=D3(I,K2(J+1))
   31 D3(I,K2(J+1))=0.
C CALCULATE B
   39 MM=0
    5 MM=MM+1
      IF(MM.EQ.1)READ(9,AA)(E1(2,I),I=1,N1),(E2(2,I),I=1,N2)
      IF(MM.GT.1)READ(13,10)(E1(2,L(I)),I=1,M1),(E2(2,M(I)),I=1,M3)
      IF(MM.GT.1)REWIND 13
      READ(9,AA)(E1(1,I),I=1,N1),(E2(1,I),I=1,N2)
   32 CALL MRPRD(D2,E2,N1,N2,1,2)
      CALL MRPRD(D3,E2,N1,N2,2,3)
      DO 33 I=1,N1
   33 E0(I)=D0(I)+R2(I)+R3(I)
      WRITE(13,10)(E0(L(I)),I=1,M1),(E2(1,M(I)),I=1,M3)
      REWIND 13
      IF(MM.EQ.1)GO TO 60
      READ(14,10)(E1(2,L(I)),I=1,M1)
      REWIND 14
   60 WRITE(12,10)(E1(1,I),I=1,N1),(E1(2,L(I)),I=1,M1),(E2(1,K1(I)),I=2,
     1NP)
C REVISE IF LAGGED CONTROL VARIABLES ARE INCLUDED
      WRITE(4,10)(E0(I),I=1,N1)
      WRITE(14,10)(E1(1,L(I)),I=1,M1)
      REWIND 14
```

```
      IF(MM.LT.NT)GO TO 5
   10 FORMAT(6E13.6)
      REWIND 12
      REWIND 4
      REWIND 9
      N=2*N1+2*NK
      RETURN
      END
C
C SUBROUTINE TRANS CONVERTS SYSTEM TO GENERAL MATRIX FORM
      SUBROUTINE TRANS(A1,N,C0,NK,D1,E3,N2,A,N1)
      REAL*8 A1(N,N),C0(N,NK),D1(N1,N1),E3(N1,N2),A(N1,N1)
      INTEGER I1/'    '/,I2/'  A '/,I3/'MATR'/,I4/'IX  '/,I5/'  C '/
      COMMON/T1/I1(35)
      DO 15 I=1,N
      DO 15 J=1,N
   15 A1(I,J)=0.
      N3=N1+1
      N4=N1+N1
      N5=N4+1
      N6=N4+NK
      N7=N6+1
      N8=N6+NK
      DO 3 I=1,N1
      DO 1 J=1,N1
    1 A1(I,J)=D1(I,J)
      DO 3 J=N5,N6
    3 A1(I,J)=E3(I,J-N4)
      DO 4 I=N3,N4
    4 A1(I,I-N1)=1.
      DO 5 I=N7,N8
    5 A1(I,I-NK)=1.
```

```
      DO 7 I=1,N
      DO 7 J=1,NK
    7 CO(I,J)=0.
      DO 6 I=1,N1
      DO 6 J=1,NK
    6 CO(I,J)=A(I,J)
      DO 8 J=1,NK
    8 CO(N4+J,J)=1.
      IF(II(34).GT.0)CALL PM(A1,N,N,I1,I1,I1,I1,I2,I3,I4,I1,I1,I1)
      IF(II(34).GT.0)CALL PM(CO,N,NK,I1,I1,I1,I1,I5,I3,I4,I1,I1,I1)
      RETURN
      END
C
C SUBROUTINE ORDER LISTS DATA FROM T TO 1 INSTEAD OF FROM 1 TO T
      SUBROUTINE ORDER(M1,M2,M3,N1,NK)
      REAL*8 X(40,40)
      INTEGER N(35),AA(40),L(40)
      COMMON/T9/AA/T1/N/T6/L/T90/X
      NT=N(13)
      NN=2*N1+2*NK
      NC=2*N1+1
      ND=NK+2*N1
      DO 20 I=1,NT
      DO 30 J=1,NN
   30 X(I,J)=0.
   20 READ(12,6)(X(I,J),J=1,N1),(X(I,L(J)+N1),J=1,M1),(X(I,J),J=NC,ND)
      REWIND 12
      DO 2 I=1,NT
      KK=NT-I+1
    2 WRITE(12,6)(X(KK,J),J=1,N1),(X(KK,L(J)+N1),J=1,M1),(X(KK,J),J=NC,N
     1D)
    6 FORMAT(6F13.6)
```

```
      REWIND 12
      DO 16 I=1,NT
   16 READ(4,6)(X(I,J),J=1,N1)
      REWIND 4
      DO 7 I=1,NT
      KK=NT-I+1
    7 WRITE(4,6)(X(KK,J),J=1,N1)
      REWIND 4
      RETURN
      END
C
C SUBROUTINE TR TRANSPOSES MATRIX A AND RETURNS MATRIX B AS TRANSPOSE
      SUBROUTINE TR(A,N,M,B)
      REAL*8 A(N,M),B(M,N)
      DO 1 I=1,N
      DO 1 J=1,M
    1 B(J,I)=A(I,J)
      RETURN
      END
C
C SUBROUTINE MINUS MULTIPLIES ALL ELEMENTS OF MATRIX A BY SCALAR -1.
      SUBROUTINE MINUS(A,N,M)
      REAL*8 A(N,M)
      DO 1 I=1,N
      DO 1 J=1,M
    1 A(I,J)=-1.*A(I,J)
      RETURN
      END
C
C SUBROUTINE CHOW SOLVES LINEAR CNTRL PROBLEM WITH QUADRATIC WELFARE LOS
C S FUNCTION USING LAGRANGIAN MULTIPLERS
      SUBROUTINE CHOW(T,HV,Y,S,X,CV,N,NK,K,W,C,CT,W2,W3,A,W4,G,AT,W6,W7,
```

```
      1N1,D,M1)
       REAL*8 K(N,N),H(N,N),C(N,NK),CT(NK,N),W2(NK,N),W3(NK,NK),A(N,N),W4
      1(NK,N),G(NK,N),AT(N,N),W6(N,N),W7(N,N)
       DOUBLE PRECISION Y,B,X,GV,T,HV,W5,D,W1,W8,DET
       INTEGER II(35),L(48)
       INTEGER J1/'    '/,J2/'OPTI'/,J3/'MAL '/,J4/'FEED'/,J5/'BACK'/,J6/
      1' ROL'/,J7/'ES  '/, J8/'  H '/,J9/'MATR'/,J10/'IX  '/,J11/'VECT'/,
      1J12/'OR  '/,J13/'  B '/,J14/'  H '/,J15/' CT '/,J16/'-CT*'/,J17/'H
      1*C '/,J18/'INV '/,J19/' H*B'/,J20/'-HV '/,J21/'CT*('/,J22/'H*B-'/,
      1J23/'HV) '/,J24/'AT*H'/,J25/'CG+A'/,J26/'(CG+'/,J27/'A)'/
       DIMENSION Y(1),B(1),LL(48),MM(48),X(1),GV(1),T(1),HV(1),W5(48),D(1
      1)
       COMMON/T30/W1(48)/T31/W8(48)/T1/II/T6/L/T40/LL/T41/MM
       NT=II(13)
       NM=0
       N3=N1+1
       N4=N1+N1
       N5=N4+1
       N6=N4+2*NK
       N7=N4+NK
       CALL RM(K,N,N)
       IF(II(31).EQ.0)GO TO 80
       CALL TITLE(J1,J1,J1,J1,J3,J9,J10,J1,J1,J1)
 80    DO 43 I=1,N
       IF(II(31).EQ.0)GO TO 81
       DO 93 J=1,N
 93    IF(K(I,J).NE.0.)WRITE(6,74)I,J,K(I,J)
 81    B(I)=0.
       Y(I)=0.
       T(I)=0.
       DO 43 J=1,N
 43    H(I,J)=K(I,J)
```

```
   94 FORMAT(' ',1X,2I4,G15.8)
      READ(12,6)(Y(I),I=1,N1),(Y(L(I)+N1),I=1,M1),(Y(I),I=N5,N7)
      CALL TR(A,N,N,AT)
      CALL TR(C,N,NK,CT)
   42 NM=NM+1
C NOTE: READ IN TARGET VARS IN REVERSE ORDER....BEGIN WITH T............
      CALL RV(T,N1)
      READ(4,6)(G(I),I=1,N1)
    6 FORMAT(6E13.6)
      IF(NM.EQ.1)GO TO 12
C CALCULATE H MATRIX
      CALL GMPRD(C,G,W6,N,NK,N)
      CALL MSUM(W6,A,N,N)
      CALL GMPRD(AT,H,W7,N,N,N)
      CALL GMPRD(W7,W6,H,N,N,N)
      IF(II(34).GT.0)CALL PM(H,N,N,J1,J1,J1,J1,J24,J25,J27,J1,J1,J1)
      CALL MSUM(H,K,N,N)
      IF(II(34).EQ.0)GO TO 69
      CALL PM(W7,N,N,J1,J1,J1,J1,J24,J1,J1,J1,J1,J1)
      CALL PM(W6,N,N,J1,J1,J1,J1,J1,J25,J1,J1,J1,J1)
      CALL PM(H,N,N,J1,J1,J1,J1,J8,J9,J10,J1,J1,J1)
C  CALCULATE H VECTOR
   69 CALL MVPRD(C,GV,W1,N,NK)
      DO 13 I=1,N
   13 W1(I)=W1(I)+G(I)
      CALL MVPRD(W7,W1,W8,N,N)
      CALL MVPRD(AT,HV,W1,N,N)
      DO 16 I=1,N
   16 W1(I)=W1(I)-W8(I)
      CALL MVPRD(K,T,W8,N,N)
      DO 19 I=1,N
   19 HV(I)=W8(I)+W1(I)
```

```
C CALCULATE G MATRIX
      GO TO 20
   12 CALL MVPRD(K,T,HV,N,N)
   20 CALL GMPRD(CT,H,W2,NK,N,N)
      CALL GMPRD(W2,C,W3,NK,N,NK)
      CALL MINV(W3,NK,DET,LL,MM)
      CALL MINUS(W3,NK,NK)
      CALL GMPRD(W2,A,W4,NK,N,N)
      CALL GMPRD(W3,W4,G,NK,NK,N)
C CALCULATE G VECTOR
      IF(II(34).EQ.0)GO TO 61
      CALL PM(H,N,N,J1,J1,J1,J1,J1,J8,J9,J10,J1,J1)
      CALL PV(B,N,J1,J1,J1,J1,J1,J13,J11,J12,J1,J1)
      CALL PV(HV,N,J1,J1,J1,J1,J1,J14,J11,J12,J1,J1)
      CALL PM(W3,NK,NK,J1,J1,J1,J16,J17,J18,J9,J10,J1,J1)
   61 CALL MVPRD(H,B,W1,N,N)
      DO 5 I=1,N
    5 W1(I)=W1(I)-HV(I)
      CALL MVPRD(CT,W1,W5,NK,N)
      CALL MVPRD(W3,W5,GV,NK,NK)
C CALCULATE OPTIMAL FEEDBACK RULES
      IF(II(34).EQ.0)GO TO 62
      CALL PM(CT,NK,N,J1,J1,J1,J1,J15,J9,J10,J1,J1,J1)
      CALL PV(W1,N,J1,J1,J1,J19,J20,J11,J12,J1,J1,J1)
      CALL PV(W5,NK,J1,J1,J21,J22,J23,J11,J12,J1,J1,J1)
   62 IF(NN.EQ.NT)GO TO 28
      DO 60 I=1,N
   60 Y(I)=0.
      READ(12,6)(Y(I),I=1,N1),(Y(L(I)+N1),I=1,M1),(Y(I),I=N5,N7)
      CALL MVPRD(G,Y,X,NK,N)
      DO 4 I=1,NK
    4 X(I)=X(I)+GV(I)
```

```
      IF(NM.GT.1.AND.II(32).EQ.0)GO TO 5
      CALL TITLE(J1,J1,J1,J2,J3,J4,J5,J6,J7,J1)
      NR=NT-NM+1
    5 WRITE(6,7)NR
    7 FORMAT(' ',4X/,' OPTIMAL CONTROL LEVELS: PERIOD',I3/)
      WRITE(6,14)(X(I),I=1,NK)
      IF(II(32).EQ.0)GO TO 28
      WRITE(6,66)
   66 FORMAT(' ',/4X,'TARGETS'/)
      WRITE(6,14)(T(I),I=1,N)
      WRITE(6,57)
      DO 90 I=1,NK
   90 WRITE(6,14)(G(I,J),J=1,N)
      WRITE(6,58)
      WRITE(6,14)(GV(I),I=1,NK)
      WRITE(6,59)
      WRITE(6,14)(Y(I),I=1,N)
      WRITE(6,70)
      WRITE(6,14)(B(I),I=1,N)
   70 FORMAT(' ',/4X,'B VECTOR'/)
   57 FORMAT(' ',/4X,'G MATRIX'/)
   58 FORMAT(' ',/4X,'G VECTOR'/)
   59 FORMAT(' ',/4X,'Y(T-1) VALUES'/)
   28 IF(NM.LT.NT)GO TO42
   14 FORMAT(' ',10G12.5)
      REWIND 12
      REWIND 4
      IF(II(32).EQ.1)REWIND 14
      RETURN
      END
C
C SUBROUTINE TITLE PRINTS APPROPRIATE PAGE HEADINGS
```

```
      SUBROUTINE TITLE(J1,J2,J3,J4,J5,J6,J7,J8,J9,J10)
      INTEGER J(10),M(20),MP/0/,B/' '/
      COMMON /T2/M/T3/ID/T4/II
      J(1)=J1
      J(2)=J2
      J(3)=J3
      J(4)=J4
      J(5)=J5
      J(6)=J6
      J(7)=J7
      J(8)=J8
      J(9)=J9
      J(10)=J10
      MP=MP+1
      JJ=0
      WRITE(6,10)II,MP
10    FORMAT('1','PROBLEM',I3,'...',33X,'...LINEAR SYSTEMS ANALYSIS PROG
     1RAM...',37X,'...PAGE',I3)
      WRITE(6,40)(J(I),I=1,10)
40    FORMAT(' ',40X,10A4)
41    GO TO (1,2,3,4,5,6,7),ID
1     WRITE(6,50)(M(I),I=1,20)
      GO TO 60
2     WRITE(6,51)(M(I),I=1,20)
      GO TO 60
3     WRITE(6,52)(M(I),I=1,20)
      GO TO 60
4     WRITE(6,53)(M(I),I=1,20)
      GO TO 60
5     WRITE(6,54)(M(I),I=1,20)
      GO TO 60
6     WRITE(6,56)(M(I),I=1,20)
```

```
      GO TO 60
 7    WRITE(6,55)(M(I),I=1,20)
60    RETURN
50    FORMAT(' ',20A4,45X,'INPUT'/)
51    FORMAT(' ',20A4,31X,'DYNAMIC MULTIPLIERS'/)
52    FORMAT(' ',20A4,28X,'RETROSPECTIVE ANALYSIS'/)
53    FORMAT(' ',20A4,30X,'PROSPECTIVE ANALYSIS'/)
54    FORMAT(' ',20A4,31X,'SIMULATION ANALYSIS'/)
55    FORMAT(' ',20A4,47X,'MAP'/)
56    FORMAT(' ',20A4,35X,'OPTIMAL CONTROL'/)
      END
```

VITA

Ray McFall Lamm, Jr. was born April 17, 1951 in Wilson, North Carolina, the son of Mr. and Mrs. Ray McFall Lamm. He graduated from Fike High School, Wilson, North Carolina, in June of 1969. In July of 1972 he graduated with honors from North Carolina State University, earning a Bachelor of Arts degree in history and economics. In July of 1974 he received a Master of Arts degree in economics with a minor in statistics from North Carolina State University. In January, 1975 he enrolled at Virginia Polytechnic Institute and State University to pursue a Ph.D. degree in agricultural economics.

From 1969 to 1971 he worked at various odd jobs while financing his undergraduate education. From 1971 to 1974 he was employed by United Parcel Service where he served as a processing plant supervisor from March 1973 until August 1974. In addition, he was a research assistant in the Department of Economics at N. C. State University in 1972 and 1973. From August of 1974 to August of 1976 he was a member of the research faculty at Virginia Polytechnic Institute and State University. Since August of 1976 he has been employed as an agricultural economist with the Commodity Economics Division, ERS, USDA.

He was married to Ann Shephard McIver of Raleigh, North Carolina on May 4, 1975.

R. McFall Lamm Jr.

A POLICY ANALYSIS OF THE UNITED STATES
VEGETABLE OILSEEDS, OILS, AND OIL PRODUCTS INDUSTRY
WITH SPECIAL EMPHASIS ON OPTIMAL CONTROL

by

Ray McFall Lamm, Jr.

(ABSTRACT)

The objectives of the study were to develop a discrete dynamic model to explain the duality of supply flows from production and inventory-stocks, to specify a monthly sectoral model of the United States vegetable oilseeds, oils, and oil products industry, to analyze policy alternatives using simulation, and to evaluate the potential of optimal control theory for stabilizing prices in the industry.

A theoretical model of consumer and producer behavior was developed which, following optimization and aggregation, yielded a 4 equation simultaneous representation of a general market system. On the basis of the theoretical model an empirical model of the industry was constructed which included 4 sub-models, each simultaneous or block simultaneous in structure. The first sub-model consisted of 14 equations and included the final products of the industry--cooking oil, shortening, margarine, and peanut butter. The second industry sub-model consisted of 17 equations and included the markets for finished soybean oil, semi-finished soybean oil, soybeans, and soybean meal. The third industry sub-model consisted of 18 equations and included the markets for finished and semi-finished cottonseed oil, peanut oil, and peanuts. The fourth sub-model consisted of 10 equations and included the markets for palm and coconut oil. Each

sub-model was estimated using OLS or 3SLS. The data base consisted of 136 observations covering the period January 1965 to April 1976.

Using 3 of the 4 sub-models, 15 deterministic policy simulation experiments were performed. The results indicated that the imposition of a tariff on palm oil over the period studied would have had little effect on finished product prices; that a decline in the price of shelled peanuts, due to an expansion in peanut production, would significantly reduce the price of peanut butter to consumers; that the soybean price support system caused the price of soybeans to be 3.3 cents greater than it would have been if no supports had been utilized; and that foreign donations of soybean oil had little impact on the soybean oil market. In addition, the results of simulation indicated that the effect of the 1973 embargo caused the price of soybeans and soybean meal to be .2 and 6 cents greater than they would have been if no embargo had been imposed; that a 5 percent increase in exports over the period studied would have increased soybean prices .5 cents; and that foreign donations of cottonseed oil had no impact on market prices over the study period.

Four experiments were performed with the soybean, soybean oil, and soybean meal sub-model using optimal control theory. Feedback control equations were derived and applied to data over the period from May 1973 to April 1976. The results were generally consistent with expectations in that the optimal policies involved the purchase of soybeans when prices were high and sales of soybeans, when prices were low (relatively). The results of the control experiments indicated that in situations where target prices and welfare objectives can be specified on a monthly basis, optimal control theory may be a useful management tool.