AN APPLICATION OF OPTIMAL CONTROL THEORY TO AGRICULTURAL POLICY ANALYSIS

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INTRODUCTION

The Problem

A commercial farm problem in the U. S. was first brought to the attention of decision makers by dissatisfied farmers in the early 1920's following drastic decreases in farm prices after World War I. The symptoms of the commercial farm problem included: chronic over-production, depressed prices for agricultural outputs and low rates of return for the factors of production. These symptoms of the farm problem have persisted over most of the last half century.

Several factors have been identified as contributing to the commercial farm problem; these are: 1) rapid technological advancements that increase agricultural productivity faster than the growth in demand for food, 2) the competitive nature of agriculture that essentially requires farmers to adopt new technology to remain in the industry, 3) resource immobility or fixity in agriculture, 4) the price inelasticity of short-run supply of agricultural products and the inelastic demand for food with respect to both price and income (Heady, 1962; Tweeten, 1970; Brandow, 1977). Many viable recommendations for solving the farm problem have stressed overcoming the underlying causes of the farm problem. Primarily the recommendations have been centered around problems associated with labor and land. The long run policy recommendation for improving the situation of excess labor in agriculture has included improved educational and skill training programs for the farm youth, creation of industrial relocation programs with subsidies for migration and improved national employment service to make the farm labor resource more mobile (Heady, 1962; Tweeten, 1970). Policy recommendations for reducing the supply of land in agriculture have included long-term land retirement, acreage allotments, and marketing quotas that restrict the amount of production in the agricultural sector (Heady, 1962; Tweeten, 1970). All of these recommendations are designed to bring the rate of return for farm labor in line with that in the non-agricultural sector. Recommendations such as Heady's and Tweeten's are directed toward a long-run solution to the farm problem but in the short-run the symptoms of the problem have been amelorated by federal farm programs.

Farm programs in the past have involved three general types of policies: direct payments to farmers, price support actions, and supply control. Reviews of the success and failures of particular farm programs can be found in Chapter 10 of Tweeten (1970) and the review of 1945-70 agricultural policy by Brandow (1977). Mandatory supply control programs have proven the most efficient in raising farm income but they have been associated with high social costs and were not acceptable to farmers as a whole. Programs that relied upon direct payments developed large treasury costs in an effort to raise farm income and usually did little to reduce over-production. Price support programs have often resulted in large stock piles of commodities and, from the standpoint of cost effectiveness, were the least effective in raising farm income. Despite the disadvantages of the farm programs, they have made it possible to reduce some of the excess capacity in agriculture without greatly reducing farm income in aggregate.

The primary interest groups involved in developing farm programs have been farmers, consumers and taxpayers. Farmers want high incomes with minimal governmental interference, consumers want a stable supply of food at low prices, and taxpayers want low treasury costs. Since these interests are conflicting and since the political powers of the groups have changed over time, farm programs have developed in a piecemeal fashion (Tweeten, 1970). These forces also have come into play in setting the values for farm policy variables such as support prices, allotments, acreage set-aside levels and target prices.

Farm programs have been used to deal with the symptoms of the farm problem in the past and as long as the farm problem exists, there is a need for economists to analyze the alternative farm programs and to make recommendations to the decision makers involved in making farm policy. However, with the added interest in government costs and the growing political powers of consumer groups, farm policy analysts are in need of a more precise performance measure than has been used in the past.

Objectives

The general objective of the thesis was to demonstrate the use of an optimal control technique for analyzing farm policy. Specific objectives were to:

1. Demonstrate the benefits from using optimal control techniques in conjunction with a simulation model over using only the latter.

2. Develop a conceptual performance measure for evaluating farm policies, given the goals of the three interest groups involved in policy decisions.

3. Indicate the type of results one can obtain from using control theory techniques to select values for farm policy variables, such as, loan rates, target prices, and acreage set-aside levels.

The objectives of the thesis were accomplished by adapting a control theory procedure to a national agricultural policy simulation model. The model selected was the National Agricultural Policy Simulator (POLYSIM), a computerized model developed by Daryll E. Ray and the author at Oklahoma State University (Ray and Richardson, 1978).

The goals of farmers, consumers and taxpayers were considered in developing a conceptual performance measure for evaluating alternative farm programs. In general, the value of the performance measure is increased as farm incomes increase and is decreased as consumer food costs increase and as government expenditures to agriculture increase. Several different types of farm programs are analyzed with optimal control techniques to determine the optimal levels of the farm policy variables, given the conceptual performance measure.

Organization of Remainder of Thesis

The remainder of the thesis is organized into four chapters. A review of control theory and the modifications to POLYSIM to adapt Box's Complex Procedure for optimal control to the model are presented in Chapter II. The mathematical relationships in the basic POLYSIM model are developed in Chapter III. Chapter IV contains the results of analyzing selected farm programs with the control theory option of POLYSIM. The summary and conclusions are presented in Chapter V.

CHAPTER II

METHODOLOGY

Optimal control theory is an applied mathematical technique developed to analyze systems under alternative sets of controls. In this study, the technique is used to determine the optimal values for agricultural farm policy variables such as: loan rates, target prices and acreage set-aside levels. The origin and applications of control theory are described in this chapter, as well as, the principles of control theory and how they are applied to agricultural policy analysis in this study.

Applications of Control Theory

The first application of control theory techniques was in the area of engineering in 1868, and used a single variable optimization technique. This work led to many other applications in the engineering area and during the second World War control theory was used extensively for studying military systems. Following the war, control theory was expanded to handle multi-variable optimization problems and was used extensively in aerospace and industrial development problems (Jacobs, 1975). It was during this stage that applied mathematicians contributed to the technique and numerous application oriented algorithms were developed (Box, 1965; Goldfeld, et al., 1966; Kendrick and Taylor, 1970; Swann, 1974; Fair, 1974; Chow, 1976). Recent contributions in the area of optimal control theory have involved the development of capabilities in stochastic and adaptive controls (Kirk, 1970; Schweppe, 1973; Cooper and Fischer, 1974; Rausser and Freebairn, 1975).

Control theory has been used extensively by a relatively small group of economists over the past decade. Textbooks in the area by Intriligator (1971), Pindyck (1973), and Chow (1975), and journal articles by Arrow (1968), Dorfman (1969), Tintner (1969), Kendrick and Taylor (1970), Livesey (1971), Pindyck and Robert (1974), Rausser and Freebairn (1974a), Arzac and Wilkinson (1977) and Trapp (1977) have demonstrated that control theory is a useful tool for analyzing economic systems. Particular economic applications range from controlling the macro level growth indicators, such as: the unemployment rate, the general price level and government spending (Pindyck, 1973) to controlling beef trade policies (Rausser and Freebairn, 1974a). With the exception of Rausser and Freebairn's (1974a) work with beef import quotas, and Trapp's (1977) work with the peanut farm program, there have been no applications of control theory to macro level agricultural policy problems, reported in the literature.

Principles of Control Theory

The objective of optimal control techniques is to determine the levels of control variables that cause a particular system (or process) to satisfy a given set of boundary constraints and at the same time cause a given performance measure to be at a maximum (or minimum) (Jacobs, 1975; Kirk, 1970; Sage, 1968). In application the control mechanism selects values for the control variables, determines their impacts on the system's output variables and evaluates the performance measure based on the values of the relevant output variables. This process is repeated in an iterative fashion until any change in the control variables results in a reduction in the value of the performance measure. To insure that the global optimal is reached the process must be repeated several times. Each time a different set of initial values for the control variables are used so the procedure is forced to search a different set of control paths.

Formulation of a control problem involves three steps: 1) development of a mathematical model of the system to be controlled; 2) a statement of the boundary constraints on the control variables and output variables; and, 3) a statement of the performance measure for the system (Kirk, 1970). The mathematical model should be a direct interpretation of the system, with particular detail given to the structure of the system and the linkages between the various sectors.

In control theory the endogenous variables in the model are referred to as the state variables (states) and are denoted as: $x_1(t)$, $x_2(t)$, ..., $x_n(t)$ for period t. The state variables used in the performance measure are referred to as the output variables or $y_1(t)$, $y_2(t)$, ..., $y_k(t)$. Exogenous variables that can be controlled by the policy maker are referred to as control inputs (controls). Controls for period t are: $u_1(t)$, $u_2(t)$, ..., $u_m(t)$; controls can be a function of time or the state variables. Values for the control variables over the period analyzed (t_o to t_f) constitute the control path or history and values for the state variables make up the state trajectory (Kirk, 1970). When the controls are not a function of the state variables ($\mu^*(t) = e[x(t_o), t]$) the system is an open-loop control problem: since once the initial control value ($x(t_o)$) is known, the entire control path is known. If controls are a function of the state variables ($\mu^*(t) = f[x(t), t]$)

the system is in the closed-loop form or optimal feedback control. Farm policy is the closed-loop form since the level of policy controls is dependent upon the levels of output variables.

Boundary constraints are usually imposed on the control variables, and can be imposed on the state variables. The constraints are used to bound the states and controls within acceptable limits established by the physical, economic and social limits of the system. This is done to reduce the number of alternative control paths that must be investigated and to reduce the computer costs of solving the problem. The model is only solved for admissible controls and admissible trajectories, where an admissible control is a control path that satisfies all constraints on the controls over the entire time period, and an admissible trajectory is a state trajectory that satisfies all constraints over the entire time period. By specifying realistic boundary constraints on the controls and the state variables, the number of admissible trajectories can be reduced thus reducing the cost of solving the model for the optimal control path.

A performance measure, the criterion for evaluating the admissible control paths, must be developed for the particular problem being investigated. The performance measure is a mathematical equation that sums the weighted values of the output variables in the model. Values of the output variables are obtained by using the admissible control paths as input in the model, to obtain simulated values for the state variables. For economic applications, the performance measure could be stated in terms of maximizing the sum of producer and consumer surpluses or following the example of Rausser and Freebairn (1974b), the performance measure could be stated as a function of the relevant output variables in the system.

Rausser and Freebairn (1974b) propose a three step procedure for specifying and estimating the performance measure in a control theory problem. The steps to the procedure are: 1) select relevant state variables as the output variables, 2) determine the appropriate mathematical form, and 3) obtain estimates of the parameters for the output variables. The guide line for selecting the output variables to include in the performance measure is quite obvious, select variables that are important to policy makers.

The mathematical form for the performance measure should formalize assumptions regarding the marginal social preference of individual output variables and the rate of substitution between the output variables. In application, the functional form needs to be as simple as possible to assign a unique real number to each set of output variables. The second step in the Rausser-Freebairn approach is identify the functional form of the performance measure. The functional form of the performance measure is dependent upon the type of problem being analyzed. For example a terminal control problem attempts to minimize the system's deviations in the final year (t_f) from some desired level of output or:

$$J = \sum_{i=1}^{n} [x_i(t_f) - r_i(t_f)]^2$$

where t_f is the final year or stage of the system and r_i is the target value for state variable i (Kirk, 1970). Another type of performance measure is for tracking problems where the objective is to keep the state variable, $x_i(t)$, as close as possible to the desired state, $r_i(t)$, over the interval t_o to t_f or:

$$J = \sum_{j=t_o}^{t_f} \left(\sum_{i=1}^{n} H_{ij} [x_i(t_j) - r_i(t_j)]^2 \right)$$

where H_{ij} is the weight assigned to the deviation for state variables i in time period j from the target level r_{ij} (Kirk, 1970; Theil, 1965; Ryan, 1974). Theil referred to this functional form as a quadratic preference function and used it for analyzing economic problems despite its obvious problem, that of using constant weights for under and over shooting the target level.

The last step in the Rausser-Freebairn procedure, estimating parameters for the performance measure is the most difficult step in applying optimal control theory to economic problems. The problem of specifying the appropriate parameters in the performance measure (H_{ij}'s) has been of little importance in the past, since the functions used by engineers in optimal control theory require only that the weights cause the model to follow a prescribed trajectory or achieve a final targeted value. Such weights can be found through experimentation or by studying the physical relationships in the system. The performance measures developed for economic applications of control theory are not generally of the tracking function form so meaningful values for the weights must be developed (Bray, 1974; Rausser and Freebairn, 1974a, 1974b, 1975).

For applications of optimal control theory to economics, the weights in the performance measure are the marginal rates of substitution of one output variable for any other output variable. Given a performance measure (PM) that is a function of three output variables, X_1, X_2, X_3 ($PM = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_1X_2 + b_5X_1X_3 + b_6X_2X_3 + b_7X_1X_2X_3$) the marginal rate of substitution of X_1 for X_2 ($MRS_{x_1x_2}$) is a ratio of their respective first derivatives or:

$$\frac{b_2 + b_4X_1 + b_6X_3 + b_7X_1X_3}{b_1 + b_4X_2 + b_5X_3 + b_7X_2X_3} .$$

The marginal rate of substitution of X_1 for X_2 measures the quantity change in X_2 for a one unit change in X_1, given that PM is unchanged. If a data series exists for PM, the function can be estimated with least squares and the parameter estimates obtained; however, the series usually can not be observed directly. A possible solution to the problem of estimating the parameters in PM is to reduce the complexity of the performance measure and normalize on a particular variable in the function. The performance measure, reduced to three terms by omitting the interaction terms and the intercept, becomes: $PM' = b_1X_1 + b_2X_2 + b_3X_3$. (In this form, PM′ can still be used as an index for comparing different outcomes of X_1, X_2, X_3.) The $MRS_{x_1x_2}$ is now b_2/b_1 and the $MRS_{x_1x_3}$ is b_3/b_1. Normalizing on X_1, making $b_1 = 1$, the marginal rate of substitution of X_1 for X_2 is b_2 and X_1 for X_3 is b_3. So when $b_1 = 1$ in PM′, the other parameters in PM′ are the marginal rates of substitution of X_1 for X_i or the ratio at which one unit of X_1 substitutes for X_i without changing the level of PM. In a national performance measure the parameters (b_i, i = 2, ..., n) are the tradeoffs between X_1 and X_i, at the margin, that are agreeable to the interest groups (and their respective political powers) involved in the political process.

Numerical Solution of Control Problems

Theoretical descriptions of optimal control theory problems generally utilize the state form (first order differential equations). Direct-solution techniques are available for solving the state form by maximizing the Lagrangian (Chow, 1975; Kirk, 1970). However, as Swann (1974) points out, direct-solution techniques may not be practical because of the lengthy and complicated calculations involved in solving the derivatives.

The problem often can be overcome with finite-difference approximations but this tends to introduce truncation and cancellation errors which can cause problems in obtaining the final solution.

An alternative to using direct-solution techniques is to use direct-search or numerical techniques. Numerical techniques do not require that the model be in the state form, and obtain the final solution without solving derivatives. Kirk (1970) and Swann (1974) describe several direct-search methods available for solving constrained optimization problems. Based on information in these and other sources (Kuester and Mize, 1973), the direct-search technique selected for this study is Box's Complex Procedure.

The Complex Procedure, developed by Box (1965), is capable of solving for the optimal set of controls in a multi-variable model that is in the form of a closed-loop feedback problem. Swann (1974) indicates that the Complex Procedure has been used quite extensively and successfully to solve a wide range of constrained optimization problems. The procedure has the flexibility of handling non-linear inequality constraints on the control variables and has been shown to be reliable when compared to more sophisticated mathematical techniques (Box, 1965; Goldfeld, et al., 1966). Since Complex is a direct-search technique, the procedure can be applied to an existing model without reprogramming the model to the state form. This was a major consideration since the model selected for this study (POLYSIM) can not be readily expressed in state form. (A computer algorithm for Complex is available in Kuester and Mize (1973) and a listing of the computer algorithm used for this study is presented in Appendix A.)

The objective of Box's Complex Procedure is to maximize the performance measure (F) subject to the boundary constraints or:

$$\text{Maximize: } F(y_1, y_2, \ldots, y_n)$$

$$\text{Subject to: } G_j \leq u_j \leq H_j, \quad j = 1, 2, 3, \ldots, m$$

where $y_1, \ldots, y_n$ are output variables, $u_1, \ldots, u_m$ are control variables, and G_j and H_j are lower and upper boundary constraints for control variable j, respectively. Values for the admissible control paths are used as input in a simulation model to obtain predicted values for the system's state variables, i.e., the state trajectory. The output variables are used in the performance measure to obtain a unique real number to be associated with the control path being evaluated.

To mathematically identify the surface of the performance measure, given m control variables, there must be at least m+1 sets of control paths. The control path associated with the lowest value for the performance measure is replaced with a path that results in a larger value for the performance measure and by repeating this replacement procedure, the maximum is eventually reached. Complex assumes convergence when the value of the performance measure for each of the m+1 points, is within β units for γ consecutive iterations. An iteration is the process that selects a new control path that does not result in repeating as the lowest function value. A more detailed description of the mechanics of Complex is available in Appendix A.

To apply Box's Complex Procedure, a FORTRAN simulation model of the system to be controlled must be provided by the user. Also, the relevant boundary constraints on the controls and a performance measure for evaluating the control paths must be specified according to the format described in Kuester and Mize (1973).

Applying Control Theory to Agricultural Policy Analysis

The objective of using control theory for farm policy analysis is to determine the farm policy instruments (control inputs) subject to boundary constraints that cause aggregate measures of the agricultural economy (output variables) to maximize (or minimize) a given performance measure. Specifically the control variables for farm policy are loan rates, target prices, and acreage set-aside levels for feed grains, wheat and cotton. The aggregate measures of the agricultural sector or output variables are net farm income, total government expenditures for farm payments, consumer expenditures for food and other aggregate variables in POLYSIM. Other state variables in the system are: crop acreage, supply, prices, domestic demands, export demands, cash receipts, ending year stocks, and livestock production, prices and cash receipts.

Model Specification

The first step in formulating a control problem for analyzing agricultural policy is to develop a mathematical model of the U. S. agricultural economy. The model used in this study is the National Agricultural Policy Simulator (POLYSIM), a disaggregated macro model of the U. S. agricultural economy with the following crop and livestock categories: feed grains, wheat, cotton, soybeans, cattle and calves, hogs, sheep and lambs, chickens, turkeys, eggs and milk (Ray and Richardson, 1978). A description of the mathematical relationships in POLYSIM is presented in Chapter III.

Boundary Constraints

The second step in formulating a control problem to analyze agricultural policy is to establish the boundary constraints on the control variables. The boundary constraints developed for the control inputs (loan rates, target prices and acreage set-aside) are presented in Tables I, II, and III. The lower boundary constraints for loan rates of wheat and corn are set at the legal minimum specified in the Agricultural Act of 1977 while the upper boundary is equal to the value of target prices in the same Act. The boundary constraints for target prices and acreage set-aside levels are tied to the Act of 1977 as indicated in Tables II and III. Constraints for the control inputs are tied to the Agricultural Act of 1977 in an attempt to incorporate the policy environment existing at the time the Act was written and passed. (Boundary constraints on state variables must appear in the performance measure when using Box's Complex Procedure.)

Performance Measure

The third step in formulating a control problem to analyze agricultural policy is the development of an aggregate performance measure for evaluating the state trajectories. The Rausser and Freebairn (1974b) procedure for identifying the performance measure is used in this study. The first stage is to determine the relavant variables to include in the performance measure. Tweeten (1970) has identified three broad political interest groups in farm policy as farm producers, consumers, and taxpayers. Farmers want farm income to be as high as possible while taxpayers want to hold down the level of payments to farmers and the

TABLE I

UPPER AND LOWER BOUNDARY CONSTRAINTS FOR LOAN RATES FOR WHEAT, CORN, AND COTTON 1978-81

Year	Wheat		Corn		Cotton	
	Lower	Upper	Lower	Upper	Lower	Upper
	$/bu.		$/bu.		$/lb.	
1978	2.00	3.00	1.75	2.10	.37	.52
1979	2.00	3.10	1.75	2.21	.37	.55
1980	2.00	3.34	1.75	2.34	.37	.58
1981	2.00	3.52	1.75	2.47	.37	.61

Source: Lower boundaries for wheat and corn 1978-81 are minimum legal values established in the 1977 Act; the legal minimum for wheat and corn is about 88 percent of the 1977 loan rate, using this for cotton we get a minimum of about 0.37; upper boundaries for all crops 1978-81, are estimated target prices over the life of the 1977 Act.

TABLE II

UPPER AND LOWER BOUNDARY CONSTRAINTS FOR TARGET PRICES FOR WHEAT, CORN, AND COTTON 1978-81

Year	Wheat Lower	Wheat Upper	Corn Lower	Corn Upper	Cotton Lower	Cotton Upper
	$/bu.		$/bu.		$/lb.	
1978	3.00	4.00	2.10	3.10	.52	.75
1979	3.16	4.21	2.21	3.26	.55	.79
1980	3.34	4.45	2.34	3.45	.58	.84
1981	3.52	4.69	2.47	3.64	.61	.88

Source: Lower boundaries for 1978 are from the 1977 Act; for analysis purposes the upper boundaries for 1978 are at about 150 percent of the 1978 lower boundaries; the 1979, 1980 and 1981 values are the 1978 values escalated by the provisions of the 1977 Act (5.4, 5.7, 5.4 percent increases in 1979-81, respectively in variable production costs).

TABLE III

UPPER AND LOWER BOUNDARY CONSTRAINTS FOR ACREAGE SET-ASIDE LEVELS FOR WHEAT, FEED GRAINS, AND COTTON 1978-81

	Wheat		Feed Grains		Cotton	
	Lower	Upper	Lower	Upper	Lower	Upper
Year	m. ac.					
1978	0	24.7	0	37.7	0	3.2
1979	0	24.8	0	37.7	0	3.3
1980	0	24.8	0	37.6	0	3.1
1981	0	24.8	0	37.5	0	3.2

Source: The Agricultural Act of 1977 specifies that the maximum acreage set-aside for cotton is 28 percent of planted acreage in the previous year. For cotton, planted acreage is about equal to harvested acreage so the maximum set-aside for cotton is 28 percent of harvested acreage in the previous year. For feed grains and wheat, planted acreage is often much larger than harvested acreage so the maximum set-aside is 35 percent of harvested acreage in the previous year.

administrative costs of farm programs. Consumers are interested in a stable and abundant supply of food at reasonable prices. Based on this information variables that should appear in a performance measure for national farm policy analysis are: farm income, government expenditures to farmers, the cost of food for consumers and other variables specific to the farm policy under consideration.

The second stage of the Rausser-Freebairn approach is to determine the mathematical form of the performance measure. The mathematical form of a performance measure for farm policy analysis can be linear, quadratic, additive or multiplicative. The additive functional form appears satisfactory for the problem at hand since farm income, government payments to farmers, and consumer food costs can be summed (with the appropriate weights) to obtain a unique real number for evaluating a particular control path. Also, there is no reason to believe that the selected variables are related in a multiplicative fashion. A quadratic form is useful if the problem is to find the optimal controls that cause the output variables to follow a particular trajectory (Theil's quadratic preference function). However, using this approach for policy analysis forces one to a priori state the target levels for each output variable without considering information generated in the process of achieving the targeted values over time.

The functional form of the performance measure developed for this study is a modified version of the tracking function or quadratic preference function; it allows the analysts to target output variables within acceptable ranges and provides a weighting procedure that differentiates between positive and negative deviations from the acceptable range. These improvements make the performance measure much more useful than the constant weight function originally used by Theil (1965). Also, the modified functional form does not force the analyst to provide single valued point estimates (targets) of the complete trajectory for the output variables but only upper and lower boundary limits. The performance measure is expressed as:

If lower bound limit is violated -

$$JL_{ij} = H_{ij} \left| Y_{ij} - LB_{ij} \right|$$

If upper bound limit is violated -

$$JU_{ij} = I_{ij} \left| Y_{ij} - UB_{ij} \right|$$

$$\text{Maximize:} \quad J = \sum_{j=1}^{4} \left(NFY_j + NLY_j - \sum_{i=3}^{n} (JL_{ij} + JU_{ij}) \right)$$

where H_{ij} is the weight for output variable Y_i violating lower boundary limit LB_i in period j; I_{ij} is the weight for output variable Y_i violating upper boundary limit UB_i in period j; NFY_j is the level of realized net farm income in period j; and NLY_j is the level of net income for livestock producers in period j. (Net income for livestock production in the study is the difference between total livestock cash receipts and variable livestock production expenses. Net income for livestock producers [about $18 billion per year] is included in the performance measure to prevent the control mechanism from increasing net income for the crop sector without regard to the impacts on the livestock sector. Farm programs that support feed prices at high levels result in high costs of feed stuffs to livestock producers which immediately reduce the net incomes for livestock producers and cause cut-backs in livestock production in the following year[s].)

The performance measure indicates that farm income is to be maximized subject to n-2 output variables. The n-2 output variables are government program costs, consumer food costs, and relevant variables for the particular farm policy being analyzed. The JL_{ij} or JU_{ij}'s are set to zero when the boundary level of an output variable is not violated, so the objective function is not penalized when the values of the output variables fall within their acceptable boundary limits.

Theil's quadratic preference function is a special case of the performance measure used here, for if $LB_{ij} = UP_{ij}$, $I_{ij} = H_{ij}$ and the deviations from the targets are squared we obtain Theil's quadratic preference function. Also, the performance measure avoids the problem of single valued target levels for the output variables. Values for the upper and lower boundary limits can be specified from observing prior decisions by decision makers and by questioning decision makers as to the acceptable ranges for the output variables.

The third step in specifying the performance measure is to estimate the parameter weights for the output variables in the function. Bray (1974) suggests that the parameter weights may be determined through interviews with decision makers and government planners. Rausser and Freebairn (1974b) refer to Bray's method as the direct approach and add to this two other approaches. The indirect approach involves studying past political decisions and the arbitrary approach involves the analyst assigning arbitrary values for the parameter weights.

The upper and lower boundary levels for the output variables in the performance measure and their respective parameter weights are presented in Table IV. No boundary levels are specified for the farm income variables (net farm income and net livestock income) since the performance measure is designed to maximize farm income subject to the other output variables. The parameter weights for the farm income variables are equal

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TABLE IV

UPPER AND LOWER BOUNDARY LEVELS AND THEIR RESPECTIVE WEIGHTS FOR AN AGGREGATE AGRICULTURAL PERFORMANCE MEASURE USED WITH POLYSIM

Output Variables$_i$ for years$_j$	Projected Values by CED Commodity Analysts (Baseline Values)	Lower Boundary Level (LB_{ij})	Upper Boundary Level (UB_{ij})	Lower Range Parameter Weights: Lower Boundary (H_{ij})	Lower Range Parameter Weights: Upper Boundary (I_{ij})	Upper Range Parameter Weights: Lower Boundary (H_{ij})	Upper Range Parameter Weights: Upper Boundary (I_{ij})
Realized Net Farm Income (m.$)							
Year 1	18,154.0			1.0	1.0	1.0	1.0
Year 2	18,426.0			1.0	1.0	1.0	1.0
Year 3	17,463.0			1.0	1.0	1.0	1.0
Year 4	17,354.0			1.0	1.0	1.0	1.0
Net Income for Livestock Producers (m.$)							
Year 1	17,312.0			1.0	1.0	1.0	1.0
Year 2	18,844.0			1.0	1.0	1.0	1.0
Year 3	19,967.0			1.0	1.0	1.0	1.0
Year 4	21,289.0			1.0	1.0	1.0	1.0
Consumers Total Expenditure for Food (m.$)							
Year 1	188,300.0	188,300.0	190,183.0	+2.0	-2.0	+4.0	-4.0
Year 2	192,500.0	192,500.0	194,425.0	+2.0	-2.0	+4.0	-4.0
Year 3	202,600.0	202,600.0	204,626.0	+2.0	-2.0	+4.0	-4.0
Year 4	211,400.0	211,400.0	213,514.0	+2.0	-2.0	+4.0	-4.0
Total Government Payments to Farmers (m.$)							
Year 1	2,054.5	850.0	3,700.0	0.0	-1.5	0.0	-4.0
Year 2	3,025.8	850.0	3,700.0	0.0	-1.5	0.0	-4.0
Year 3	3,362.9	850.0	3,700.0	0.0	-1.5	0.0	-4.0
Year 4	3,654.5	850.0	3,700.0	0.0	-1.5	0.0	-4.0
Total CCC Interest and Storage Costs (m.$)							
Year 1	310.4	0.0	600.0	0.0	-1.5	0.0	-4.0
Year 2	452.0	0.0	600.0	0.0	-1.5	0.0	-4.0
Year 3	598.8	0.0	600.0	0.0	-1.5	0.0	-4.0
Year 4	739.2	0.0	600.0	0.0	-1.5	0.0	-4.0
Ending Year Stocks of Feed Grains (m.t.)							
Year 1	70.4	30.0	60.0	-104.0	-82.5	-104.0	-82.5
Year 2	82.6	30.0	60.0	-104.0	-82.5	-104.0	-82.5
Year 3	87.5	30.0	60.0	-104.0	-82.5	-104.0	-82.5
Year 4	89.3	30.0	60.0	-104.0	-82.5	-104.0	-82.5
Ending Year Stocks of Wheat (m.bu.)							
Year 1	1,539.0	600.0	1,200.0	-3.4	-2.8	-3.4	-2.8
Year 2	1,827.0	600.0	1,200.0	-3.4	-2.8	-3.4	-2.8
Year 3	2,112.0	600.0	1,200.0	-3.4	-2.8	-3.4	-2.8
Year 4	2,374.0	600.0	1,200.0	-3.4	-2.8	-3.4	-2.8
Ending Year Stocks of Cotton (m.bales)							
Year 1	4.3	2.0	4.0	-284.8	-268.6	-284.8	-268.6
Year 2	4.2	2.0	4.0	-284.8	-268.6	-284.8	-268.6
Year 3	4.5	2.0	4.0	-284.8	-268.6	-284.8	-268.6
Year 4	4.1	2.0	4.0	-284.8	-268.6	-284.8	-268.6

to 1.0, indicating that the value of the performance measure is increased one unit for each one unit increase in farm income and vice versa (Table IV). The parameter weights of 1.0 for the farm income variables are dictated by the decision to normalize the parameters in PM′ on the farm income variables.

The cost of food to consumers in the U. S. or consumer's total expenditures for food is one of the primary output variables in the performance measure. The baseline values for consumer's total expenditures for food by commodity analysts in CED, USDA are presented in Table IV; these values are used as lower boundary levels, LB_{3j}, in the performance measure. The upper boundary levels for total food costs, UB_{3j}, are set at 101 percent of the baseline values. Food costs are generally measured in terms of a percentage change in total per capita food costs from year to year. The baseline values assume a per capita increase in food costs of three to four percent per year over the study period. So the one percent increase, used to obtain the upper boundary levels, puts the annual increase in food costs at about four to five percent. The value of total food costs is free to move within the upper and lower boundary levels (say between $188,300 million and $190,183 million in year 1) without changing the performance measure. However, values outside these boundary levels cause the performance measure to be changed according to the parameter weights identified for the output variable.

Two alternative sets of parameter weights or ranges are presented in Table IV for several of the output variables. The lower and upper boundary parameter weights, H_{ij} and I_{ij}, for consumer's total expenditures for food are +2.0 and -2.0 for the lower range and +4.0 and -4.0 for the upper range, respectively. Parameter weight +2.0 (H_{ij} in the lower range) implies that each dollar decrease in total food costs below the lower boundary level increases the value of the performance measure by two units. So if total food costs in the U. S. decreased below the boundary level by an average of \$1 per consumer, the performance measure would be increased by about 440 million units. The upper boundary parameter weight -2.0 (I_{ij} for the lower range) implies that each \$1 increase in total food costs, above the upper boundary level, reduces the value of the performance measure by two units.

Values for the parameter weights in the lower range were selected based on the assumption that a \$220 million increase in consumer expenditures for food (\$1 per consumer) decreases the performance measure by about 440 million units or 1:-2 (Table IV). The upper range parameter weights reflect a trade-off of 1:-4 or twice the impact as the lower range. The lower range parameters are used to evaluate all four farm programs in the study and the upper range values are used to evaluate one of the four programs to demonstrate the sensitivity of the optimal solution to changes in the performance measure.

Government expenditures for the U. S. farm program are separated into two categories, direct payments to farmers and Commodity Credit Corporation (CCC) storage and interest costs. The annual baseline values for government payments and CCC costs over the study period are presented in Table IV. The lower boundary level for direct payments to farmers, LB_{4j}, is set at the baseline estimate of government payments for miscellaneous farm programs. The upper boundary level for government payments, UB_{4j}, is set at \$3,700 million, the baseline estimate of total payments during the last year of the study, 1981. The lower boundary level for CCC storage and interest costs, LB_{5j}, is set at zero while the upper boundary level, UB_{5j}, is set at \$600 million (Table IV). The value for the upper boundary of CCC costs comes from the storage and interest costs for holding a reserve of 30 million tons of feed grains and 600 million bushels of wheat. (Values for the quantity of CCC reserves come from recommendations by Waugh [1967], Tweeten, Kalbfleisch and Lu [1971] and historical values for ending year stocks of feed grains and wheat. Waugh recommends a feed grain reserve of 30-40 million tons and a wheat reserve of 550 to 650 million bushels. Tweeten et al. recommends a wheat reserve of 600 million bushels.)

Parameter weights for total government payments to farmers and CCC storage and interest costs are assumed to be equal for this study since both variables represent costs to the taxpayer for having farm programs. The lower and upper boundary parameter weights, H_{ij} and I_{ij}, for government expenditures are 0.0 and -1.5 for the lower range and 0.0 and -4.0 for the upper range, respectively (Table IV). A zero lower boundary parameter weight is selected for these variables in both ranges since it is not possible to have government payments or CCC costs below the lower boundary levels established in Table IV. The upper boundary parameter weights -1.5 and -4.0 indicate that a dollar of government expenditures above the upper boundary level (LB_{ij}) causes the performance measure to be decreased by more than a dollar or \$1.50 and \$4, respectively. Weights for the upper boundary levels on government payments to farmers and CCC storage and interest costs indicate the marginal disutility that taxpayers receive for each unit of expense over the upper boundary level of \$3,700 million and \$600 million, respectively. A weight of -1.5 implies that for each additional dollar the disutility is \$1.5 or half again more than the actual cash outlay.

Total ending year carryover of feed grains, wheat and cotton are included in the performance measure (J) to penalize the value of the performance measure when shortages or surpluses of these crops are encountered. The lower boundary levels (LB_{ij}) are set at 30 million tons of feed grains, 600 million bushels of wheat, and 2 million bales of cotton (Table IV). These values are in line with optimal carryover levels reported by Tweeten, Kalbfleisch and Lu (1971) and Waugh (1967). The upper boundary levels (UB_{ij}) are set at about twice the lower boundary levels for all three crops.

Upper boundary parameter weights (I_{ij}), for penalizing the performance measure when ending year carryovers of feed grains, wheat and cotton exceed their respective upper bounds (UB_{ij}), are stated in terms of the costs to society associated with a "surplus carryover". (A "surplus carryover" is defined as an ending year carryover in excess of the relevant upper boundary level.) The costs to society of a surplus carryover is the sum of direct costs (interest and storage charges) and opportunity costs for the resources used to produce the surplus carryover. Annual storage costs for feed grains are about $7.20 per ton and for wheat the costs is about $0.22 per bushel. Annual storage cost for cotton is about $5.40 per bale. (Storage costs used here are based on values used by commodity analysts in CED, ERS, USDA to estimate total CCC storage costs.) Interest charges for CCC storage are 7.5 percent of the value of the stock, where value is based on the average loan rate.

The opportunity cost to society for surplus carryovers is the value of resources used in producing the surplus stocks. Theoretically the opportunity cost (marginal cost of production) for producing excess carryovers is measured as the area under the supply curve, associated with the quantity of excess production (Tweeten, 1970). It is assumed in this study that the average per unit marginal (variable) cost of production for excess carryover is the particular crop's loan rate. This is a reasonable assumption since at high stock levels the market price is likely to equal the loan rate. Using the announced loan rates in the Agricultural Act of 1977 ($2.00/bushel for corn, $2.35/bushel for wheat and $0.51/lb. for cotton) the marginal (variable) cost of production for surplus carryovers are: $70 per ton of feed grains, $2.35 per bushel of wheat, and $244.80 per bale of cotton. Thus for feed grains the upper boundary parameter weight (I_{ij}) is -82.5 per ton or the sum of storage costs ($7.20/ton), interest costs ($5.30/ton) and the marginal (variable) cost of production ($70/ton). So for every ton of feed grains in ending year carryover above 60 million tons, the performance measure is reduced 82.5 units. The upper boundary parameter weight for ending year stocks of wheat is -2.8 or for each bushel of wheat above 1,200 million bushels the performance measure is reduced by 2.8 units. The parameter weight for ending year stocks of cotton exceeding the upper boundary is -268.6 (Table IV).

The lower boundary parameter weights for ending year carryovers of feed grains, wheat and cotton should be larger, in absolute terms, than the respective upper boundary parameter weights for these output variables. Higher parameter weights are justified because as ending year stocks get smaller the greater the possibility that they will be needed to meet domestic demands. The lower boundary parameter weights (H_{ij}) for feed grain, wheat and cotton ending year carryovers are: -104.0, -3.4 and -284.8, respectively (Table IV). The lower boundary parameter weights used in the study reflect higher storage costs than the upper boundary weights, to account for society's increased marginal value of holding a reserve in the face of relatively tight supplies.

Modifications Made to POLYSIM

To incorporate Box's Complex Procedure in the POLYSIM model, several changes were made that affect data input and the order in which model components are executed. The original data cards required for POLYSIM are described in Richardson and Ray (1975a), and coding instructions for additional data cards required for the Control Theory Option are presented in Appendix B.

When the Control Theory Option is specified, the POLYSIM model calls the Complex Procedure which solves for a maximum value of the performance measure in an iterative fashion (Figure 1). The Complex Procedure selects admissible control paths, for the policy variables in the farm programs specified by the user. The user must provide the upper and lower boundary constraints for the policy (control) variables in subroutine CONST and the constraint subroutines it calls (see Appendix A).

The admissible control paths are used as the policy changes to be simulated and the subroutines in the model are executed to obtain the simulated values for the state variables (Figure 1). The simulated values for the output variables are used in the performance measure to evaluate the particular control path. The performance measure is provided by the user in subroutine OBJT (see Appendix A). Also, the user must provide the boundary levels and parameter weights for the performance measure (see Appendix B).

The process of selecting control paths, executing the POLYSIM subroutines, and evaluating the performance measure is repeated until the

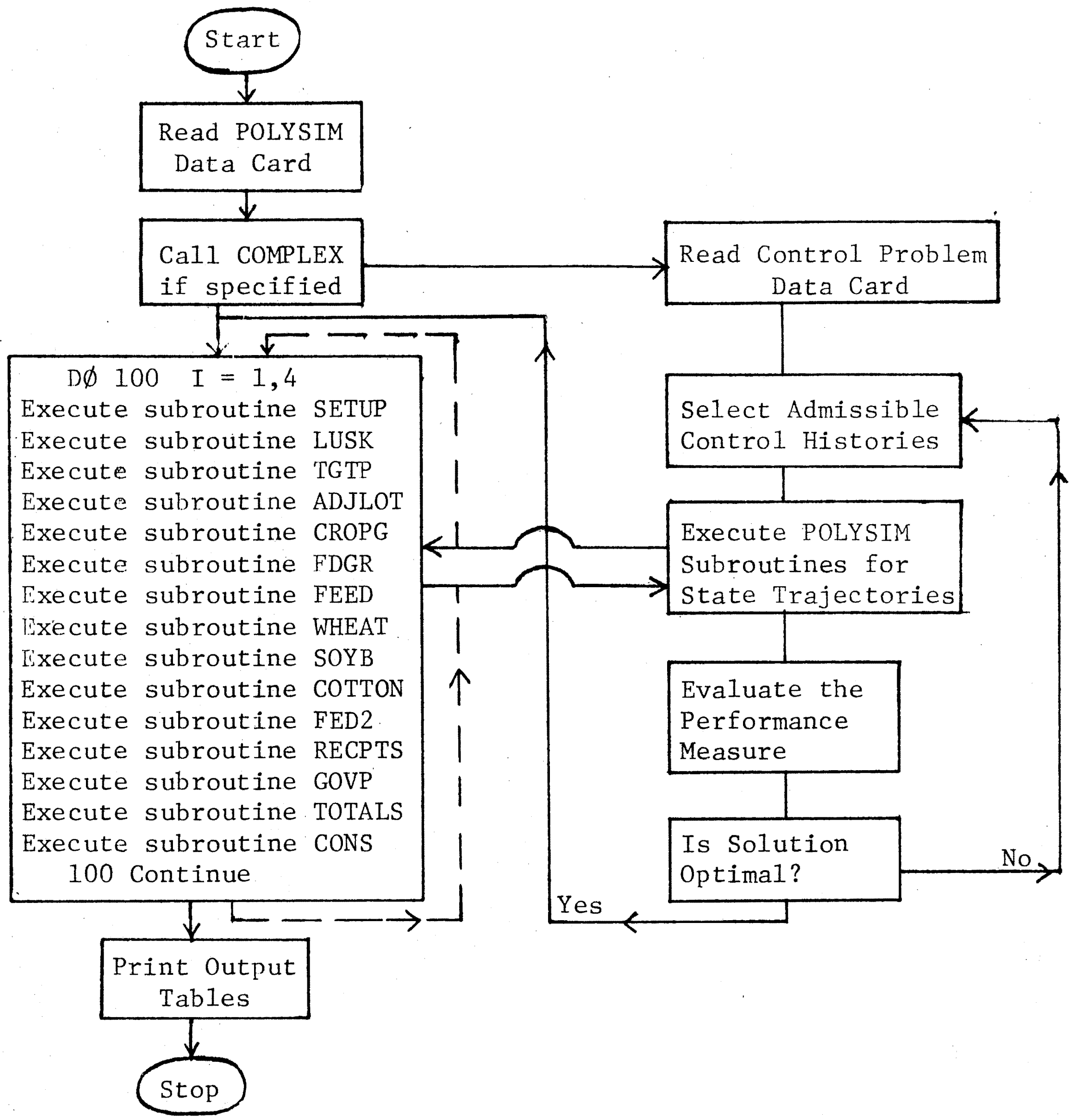

Figure 1. Flowchart of POLYSIM and Its Modifications for the Control Theory Option

optimal control path is found. When the optimal control history is determined the program re-enters POLYSIM, executes the subroutines in the model and prints the results in the normal output tables (Figure 1).

CHAPTER III

A DESCRIPTION OF THE POLYSIM MODEL

Overview of the Model

POLYSIM was constructed differently from most simulation models to insure compatability with other policy analyses of the ERS. The model makes full use of forecasted data as a reference baseline. Included are the five-year baseline projections of commodity supplies, prices, and utilization made by ERS. Commodity specialists develop these projections using formal and informal forecasting models tempered with their own experienced judgments. The projections contain explicit assumptions concerning the rates of change in population, per capita incomes, consumer preferences, export demand, technology (including crop yields and livestock gains), and other supply and demand shifters. These projections also assume a specific set of Government farm programs. In most policy analyses, the basic supply and demand shifters remain unchanged. It is the policy related shifts and indirect economic responses through the price mechanism that count in analyzing the impacts of alternative policy proposals. POLYSIM simulates the effects of policy specifications that differ from those assumed in the baseline while holding all other supply and demand shifters the same. The model thus focuses on the interaction of supply and demand responses that result from specified changes in policy variables.

Commodity supply and demand elasticities represent an important part of POLYSIM. The driving forces in the model are the initial and subsequent changes in commodity prices resulting from changes in policy conditions. The magnitude of impact is determined by direct and cross supply and demand elasticities. The elasticities used in the model were developed in stages. Initially, a comprehensive literature review was made to gather past estimates of the required elasticities. Secondly, many of the elasticities were reestimated, using more recent data. Finally, to make the model more useful to ERS, commodity specialists reviewed the estimates, which had been categorized by commodity groups. The final revised estimates are used as default values in the model, but users can change any of the elasticities if they have better or more recent information. (Appendix A of Ray and Richardson (1978) contains a complete description of the elasticities used in POLYSIM.)

Commodities included in the model are feed grains, wheat, soybeans, cotton, cattle and calves, hogs, sheep and lambs, chickens, turkeys, eggs, and milk. As indicated earlier, the model is designed to simulate around a set of baseline conditions. Base estimates must be available for all years analyzed in the simulated time frame. To date, most applications have been for a time horizon of three to five years.

The user starts a simulation by changing one or more of the policy assumptions used in the base conditions; for example, by using a different series of loan rates. The simulation procedure traces through the effects on production, price, utilization, and farm income for each of the eleven commodity groups and on agriculture in the aggregate. Elasticities are used to calculate new values for the endogenous variables as deviations away from the base values. To simulate a change in an endogenous variable such as feed grain acreage, the percentage change between simulated and base estimates for the expected price variables is multiplied by direct and cross price elasticities. This operation results in a percentage change in feed grain acreage which is used to obtain a simulated value under the new policy assumptions.

The calculation procedure used by POLYSIM is similar to the hand calculations an analyst might use to estimate the impact of a change in an economic variable. Suppose a previous analysis indicated that farmers would plant 110 million acres of feed grains given the expected price for feed grains and other assumed conditions. If an analyst were asked to estimate a new feed grain acreage assuming a ten percent increase in feed grain price (ceteris paribus), he probably would use an estimate of the elasticity of feed grain acreage with respect to feed grain price in his calculations. Specifically he would determine the percentage change in feed grain acreage by multiplying the elasticity of feed grain acreage wrt feed grain price (say .1) times the percent change in price, i.e., ten percent X .1 = one percent. To obtain the new level of feed grain acreage he would convert the percentage change in acreage to a decimal (.01), add it to 1.0 and multiply the result (1.01) times the initial feed grain acreage of 110. The estimated acreage would be 1.01 X 110 = 111.1.

POLYSIM uses this general calculation approach as is illustrated in the following example relationships for feed grain acreage and cattle and calf production. The percentage change in the left-hand variable calculated by the model is the sum of products of the elasticities and percentage changes in the right-hand variables (from their baseline values). The resulting percentage change in the left-hand variable is added to

Percentage Change In	Elasticity	Due to Percentage Change In
Feed Grain Acreage (t)	.10	Expected feed grain price (t)
	-.03	Expected wheat price (t)
	-.06	Expected soybean price (t)
Cattle and Calf Production (t)	.11	Cattle and calf price (t-1)
	-.02	Hog price (t-1)
	-.01	Sheep and lamb price (t-1)
	-.05	Feed grain price (t-1)

Figure 2. Example Relationships for Feed Grain Acreage and Cattle and Calf Production

1.0 and multiplied by its base value. Although not included in the example, each quantity equation has a geometrically distributed lag structure to allow multi-period response to price.

The model is described in three parts or segments. The first segment describes the livestock production and consumption activities in the model. The second segment details the crop production and consumption portion of the model. The concluding segment describes the accounting identities for developing aggregate income estimates. Each segment contains a description of the equations used to estimate the output variables, as well as, a discussion of the farm policy provisions or variables that influence the output variables.

Livestock Production and Consumption

Livestock Production

POLYSIM begins each simulation year by computing the level of production for each of the livestock categories. Production is measured in millions of pounds of carcass weight for cattle and calves, hogs, and sheep, and in millions of pounds of ready-to-cook weight for chickens and turkeys. Egg production is measured in millions of dozens and milk production is in terms of millions of pounds of milk equivalents.

Following economic theory, the baseline value for each livestock group's production is adjusted up or down in response to changes in the expected price of the particular livestock group, and changes in the expected price of feed. Specifically, the production of cattle and calves responds to expected changes in own price, hog price, milk price and the price of feed grains. Due to the time lag in the production process, previous year prices are used as the expected prices in determining production response. Hog and sheep production is dependent upon their own price, cattle and calf price and feed grain price. Broiler, turkey and egg production is a function of their own price and the price of feed grains. Milk production is a function of expected changes in own price, cattle and calf price and the feed grain price.

Livestock production values are computed by a single equation for each livestock category. The appropriate prices in the equation are related to the dependent variables (million pounds of production) through elasticities; the hog production equation (1) demonstrates the mechanics of associating the appropriate prices and elasticities.

$$\begin{aligned}\text{Simulated Hog Prod. m. lbs.}_t = {} & \text{Baseline Hog Prod. m. lbs.}_t * \Big[1.0 + \Big\{ \text{elasticity hog prod. wrt hog price} * \text{\% change hog price from baseline}_{t-1} \Big\} + \\ & \Big\{ \text{elasticity hog prod. wrt cattle and calf price} * \text{\% change cattle and calf price from baseline}_{t-1} \Big\} + \Big\{ \text{elasticity of hog prod. wrt feed grain price} * \\ & \text{\% change feed grain price from baseline}_{t-1} \Big\} \Big] + \left(1.0 - \text{long run adjustment factor} \right) * \left(\text{simulated hog prod.}_{t-1} - \text{baseline hog prod.}_{t-1} \right) \qquad (1)\end{aligned}$$

The interpretation of equation (1) is as follows. The estimated level of hog production is obtained by adjusting baseline hog production to reflect supply response from changes that may have occurred in lagged prices of hogs, cattle and calves and feed grains. The price changes are in terms of percent of baseline prices. The effect of each price change (say, price of hogs) on production is estimated as the product of the percentage change in price and the elasticity of hog production with respect to the price. The net first-year effect of all price changes on production is the sum of products of the percentage price changes and associated elasticity. This net first-year effect (expressed as a decimal) is added to one and multiplied times baseline hog production to obtain a new production level that is consistent with the prices. Since complete response to price change is not immediate but is distributed over a number of time periods, a geometrically distributed lag structure is also included. The level of hog production in year t will be influenced not only by changes in prices that occurred in t-1 but also in previous periods. The ratio of short-run to long-run elasticities is used to compute the Nerlovian adjustment coefficient for the distributed lag portion of the equation.

A numerical example may be helpful in understanding what takes place in equation (1).

$$15033.6 = 14700.0 * [1.0 + (0.30 * \frac{0.39 - 0.38}{0.38}) + (-0.04 * \frac{0.43 - 0.44}{0.44}) + (-0.25 * \frac{1.64 - 1.75}{1.75})] + (1.0 - 0.5) * (1.338.0 - 13380.0)$$

In the example, hog price increases by one cent per pound from the baseline value of 38¢, cattle and calf price decreases one cent and corn price decreases eleven cents per bushel. The first year impact of these price changes is to adjust the baseline value for hog production up by 333.6 million pounds. If there are no price changes in the following year (t+1), the baseline production will be increased by 166.87 million pounds or (1.0 - 0.5) * (15033.6 - 14700.0), due to the lagged production response to the change in price in t.

The own and cross price elasticities for the livestock production equations are presented in Table V. Each row of the table gives the default elasticities for the respective livestock production equation which follows the form of equation (1). For example, the cattle and calf production equation has an own supply elasticity of +.110, cross supply elasticities for hog price and sheep price of -.005 and -.001, respectively, and a supply elasticity with respect to feed grain price of -.050. The production equations for the red meat groups contain cross supply elasticities because of the possibility of substitution across these categories. On the other hand, the default cross elasticities of supply for the poultry categories are zero because the facilities and management for producing each poultry group is relatively specialized.

Livestock Consumption

The quantity of livestock available for domestic consumption is production plus imports minus exports. Imports and exports of livestock are exogenous to the system and as such, are held constant at baseline levels (unless livestock import or export programs are being investigated).[1] As the quantity of beef available for domestic consumption

[1] It is assumed that ending year cold storage inventories are equal to beginning year inventories.

TABLE V

DEFAULT ELASTICITIES FOR LIVESTOCK PRODUCTION[1]

Elasticity of	Cattle & Calf $Price_{t-1}$	Hog $Price_{t-1}$	Sheep $Price_{t-1}$	Chicken $Price_{t-1}$	Turkey $Price_{t-1}$	Egg $Price_{t-1}$	Milk $Price_{t-1}$	Feed Grain $Price_{t-1}$
Cattle and Calf $Production_t$	.110 (.440)	-.005 (-.020)	-.001 (-.004)					-.070 (-.280
Hog $Production_t$	-.040 (-.080)	.300 (.600)	-.005 (-.010)					-.250 (-.500)
Sheep $Production_t$	-.010 (-.020)		.025 (.050)					-.040 (-.080)
Chicken $Production_t$				.260 (.364)				-.220 (-.358)
Turkey $Production_t$					.250 (.425)			-.200 (-.340)
Egg $Production_t$						.100 (.150)		-.060 (-.090)
Milk $Production_t$							.100 (.250)	-.060 (-.150)

Source: Appendix A, Section 1 of Ray and Richardson (1978).

[1]Long-run elasticities are in parentheses under the respective short-run elasticity.

increases the price received by farmers for cattle and calves decreases, other things constant. For a disaggregated model, such as POLYSIM, it is not acceptable to compute prices for each livestock category without considering the other livestock categories. Economic theory and emperical findings (George and King, 1971; Brandow, 1961) indicate there is a significant cross price relationship between the major livestock categories. The Brandow and the George and King matrices of own and cross farm level price flexibilities for the seven major livestock categories are presented in Table VI. The matrix of price flexibilities provided by the Commodity Economics Division, ERS, USDA is also given in Table VI.

Livestock prices are computed using one of the price flexibility matrices and computed percentage changes in the quantity available for domestic consumption from their respective baseline values. The user must specify which of the farm level price flexibility matrices in Table VI is to be used.[2]

In computing cattle and calf prices, the first row of the selected price flexibility matrix is multiplied times the percentage change in the quantity available for domestic consumption for the corresponding commodity. The seven multiplication products are summed, added to 1.0, and the result is multiplied times the baseline cattle and calf price. Equation (2) displays the computation procedure.

---

[2]The CED matrix was developed by commodity analysts in CED, USDA to reflect the influence of grass fed beef on the market. The matrix is a hybrid of the Brandow matrix, the George and King matrix, and new coefficients for the cattle price flexibility wrt cattle available and for the chicken price flexibility wrt cattle availability.

TABLE VI

THREE SETS OF DEMAND EQUATIONS FOR LIVESTOCK AND LIVESTOCK PRODUCTS AT THE FARM LEVEL, EXPRESSING PRICES AS A FUNCTION OF QUANTITY

Logs of Prices of	BRANDOW MATRIX[1] - Logarithm of Quantities of:						
	Cattle[2]	Hogs[2]	Sheep and Lambs[2]	Chickens[2]	Turkeys[2]	Eggs[3]	Milk[4]
Cattle[5]	-1.5862	-.2787	-.0363	-.1458	-.0248	-.0245	-.0283
Hogs[5]	-.4180	-2.3269	-.0478	-.1929	-.0331	-.0351	-.0407
Sheep and Lambs[5]	-.5026	-.4460	-.4832	-.1917	-.0317	-.0212	-.0243
Chickens[5]	-.4750	-.4205	-.0450	-1.4907	-.1375	-.0301	-.0347
Turkeys[5]	-.3112	-.2757	-.0295	-.5364	-1.1332	-.0265	-.0307
Eggs[6]	-.1018	-.0856	-.0068	-.0348	-.0087	-3.5000	-.0648
Milk[7]	-.0506	-.1189	-.0033	-.0172	-.0043	-.0230	-2.6390

Logs of Prices of	GEORGE AND KING MATRIX[1] - Logarithm of Quantities of:						
	Cattle[2]	Hogs[2]	Sheep and Lambs[2]	Chickens[2]	Turkeys[2]	Eggs[3]	Milk[4]
Cattle[5]	-2.3946	-.9051	-.0746	-.2716	-.0268	-.0270	-.0271
Hogs[5]	-.7184	-4.7626	-.1231	-.2774	-.0296	-.0693	-.0696
Sheep and Lambs[5]	-.5845	-.6916	-.6673	-.3299	-.0303	-.0420	-.0422
Chickens[5]	-.9064	-.9825	-.0936	-1.8671	-.1011	-.0471	-.0472
Turkeys[5]	-.4315	-.5858	-.0416	-.5126	-.7962	-.0207	-.0208

TABLE VI (CONTINUED)

Logs of Prices of	GEORGE AND KING MATRIX[1] - Logarithm of Quantities of:						
	Cattle[2]	Hogs[2]	Sheep and Lambs[2]	Chickens[2]	Turkeys[2]	Eggs[3]	Milk[4]
Eggs[6]	-.2683	-.4699	-.0262	-.0926	-.0163	-4.3350	-.4316
Milk[7]	-.0884	-.1313	-.0089	-.0282	-.0060	-.1750	-3.1801

Logs of Prices of	CED LIVESTOCK MATRIX[1] - Logarithm of Quantities of:						
	Cattle[2]	Hogs[2]	Sheep and Lambs[2]	Chickens[2]	Turkeys[2]	Eggs[3]	Milk[4]
Cattle[5]	-1.6446	-.9051	-.0746	-.2716	-.0268	-.0269	-.0271
Hogs[5]	-.7184	-2.3269	-.0478	-.1929	-.0331	-.0351	-.0407
Sheep and Lambs[5]	-.5026	-.4460	-.4832	-.1917	-.0317	-.0212	-.0243
Chickens[5]	-.7750	-.4205	-.0450	-1.4907	-.1375	-.0301	-.0347
Turkeys[5]	-.4612	-.2757	-.0295	-.5364	-1.1332	-.0265	-.0307
Eggs[6]	-.2684	-.4699	-.0262	-.0926	-.0164	-4.3350	-.4316
Milk[7]	-.0885	-.1313	-.0089	-.0282	-.0060	-.1750	-3.1801

TABLE VI (CONTINUED)

[1]Source: Appendix A, Section 2 of Ray and Richardson (1978).

[2]Million pounds slaughtered.

[3]Million dozen sold.

[4]Million hundred weight sold.

[5]Dollars per pound.

[6]Dollars per dozen.

[7]Dollars per hundredweight.

$$
\begin{aligned}
\text{Simulated cattle and calf price}_t = {} & \text{Baseline cattle and calf price}_t * \Bigg[1.0 + \left(\text{own price flexibility for cattle and calves} * \text{\% change in cattle \& calves available from baseline}_t\right) \\
& + \left(\text{cross price flexibility for hogs} * \text{\% change in hogs available from baseline}_t\right) + \left(\text{cross price flexibility for sheep} * \text{\% change in sheep available from baseline}_t\right) \\
& + \left(\text{cross price flexibility for chicken} * \text{\% change in chicken available from baseline}_t\right) + \left(\text{cross price flexibility for turkey} * \text{\% change in turkey available from baseline}_t\right) \\
& + \left(\text{cross price flexibility for eggs} * \text{\% change in eggs available from baseline}_t\right) + \left(\text{cross price flexibility for milk} * \text{\% change in milk available from baseline}_t\right)\Bigg] \qquad (2)
\end{aligned}
$$

An equation similar to (2) is used to calculate the price received by farmers for each of the remaining six livestock categories. The percentage change in quantities of all seven commodities are used for all price equations along with the appropriate row of the selected matrix. For example, if the Brandow matrix is selected (Table VI), the hog price equation would use -0.4180, the cross price flexibility of hog price to the quantity of beef available, -2.3269, the own price flexibility of hog price, and so on.

Estimated livestock prices for period t are used to compute livestock cash receipts in period t and the livestock demand for feed grains in t. These t period prices are also used to estimate livestock production in the following period (t+1). The livestock cash receipts equations are discussed in a later section.

Indices of the Livestock Sector

POLYSIM provides estimates of the total number of livestock production units (grain-consuming animal units) and the index of prices received for livestock products as well as production and price estimates for the seven major livestock categories. Livestock production units is an index series relating the number of livestock and poultry fed on farms during a given year to the feeding requirements of each major livestock category, in terms of different grains, high protein feeds and roughages (USDA, 1970). Grain consuming animal units are particular interest in the POLYSIM model.

The baseline level of livestock production units is modified if production in any of the seven livestock categories is different from their respective baseline levels. The factors which are applied to the difference between the baseline and calculated production levels are the same as those used by the USDA to construct the baseline livestock production units series (USDA, 1975). Equation 3 illustrates the computation procedure.

$$
\begin{aligned}
\text{Calculated livestock production units}_t = {} & \text{Baseline livestock production units}_t + \left\{ \left(\text{calculated beef production}_t - \text{baseline beef production}_t \right) * \text{beef weight in livestock production units} \right\} \\
& + \left\{ \left(\text{calculated hog production}_t - \text{baseline hog production}_t \right) * \text{hog weight in livestock production units} \right\} \\
& + \left\{ \left(\text{calculated sheep production}_t - \text{baseline sheep production}_t \right) * \text{sheep weight in livestock production units} \right\} + \cdots\cdots\cdots \\
& + \left\{ \left(\text{calculated milk production}_t - \text{baseline milk production}_t \right) * \text{milk production weight in livestock production units} \right\}
\end{aligned}
\qquad (3)
$$

The index of prices received for livestock and livestock products is calculated in the model as an adjustment in the baseline index number for changes in the calculated prices received for livestock from their respective baseline values (4).

$$\begin{pmatrix}\text{Calculated index}\\ \text{of prices received}\\ \text{for livestock}_t\end{pmatrix} = \begin{pmatrix}\text{Baseline index of}\\ \text{prices received}\\ \text{for livestock}_t\end{pmatrix} * \Bigg[1.0 + \begin{pmatrix}\text{cattle and}\\ \text{calves weight}\\ \text{in the index}\end{pmatrix} * \begin{pmatrix}\text{\% change in cattle}\\ \text{and calves price}\\ \text{from baseline}_t\end{pmatrix} + \begin{pmatrix}\text{hogs weight}\\ \text{in the}\\ \text{index}\end{pmatrix} * \begin{pmatrix}\text{\% change in}\\ \text{hog price from}\\ \text{baseline}_t\end{pmatrix} + \ldots\ldots + \begin{pmatrix}\text{milk prices}\\ \text{weight in}\\ \text{the index}\end{pmatrix} * \begin{pmatrix}\text{\% change in}\\ \text{milk price}\\ \text{from baseline}_t\end{pmatrix}\Bigg] \quad (4)$$

The sum of the weighted percentage changes in livestock prices is multiplied by the baseline index number to get a calculated index number. The baseline index number implicitly contains the baseline prices received for each of the seven livestock categories and prices received for all other livestock products. By assuming that the prices of all other livestock products remain fixed at their baseline levels, the calculated index number need only be adjusted for relative changes in the prices of the seven livestock categories in the model. The weights for the individual livestock categories are used in (4) to appropriately weight the change in prices.

Crop Production and Utilization

Crop Production

The crop production section of POLYSIM includes equations for estimating harvested acreage, yield, and variable production expense per harvested acre for each of the four crops in the model (feed grains, wheat, soybeans, and cotton). Crop production is computed as the product of yield and harvested acreage. Feed grain production is in terms of million tons, while wheat and soybeans are in terms of million bushels. Cotton production is measured in millions of net bales.

Harvested Acreage

To estimate the harvested acreage for each crop, the baseline harvested acreage value is adjusted for farmer response to changes in expected crop prices from their respective baseline levels. Percentage change in crop price and prices of the other three crops are weighted by the direct and cross supply elasticities to arrive at the percentage adjustment in the base acreage value. An example of the calculation approach is given by equation (5) for feed grains harvested acreage.

$$
\begin{array}{l}\text{Simulated feed}\\ \text{grain harvested}\\ \text{acreage m. acres t}\end{array} = \begin{array}{l}\text{Baseline feed grain}\\ \text{harvested acreage}\\ \text{m. acres t}\end{array} * \Bigg[1.0 + \left(\begin{array}{l}\text{elasticity of}\\ \text{fg acreage}\\ \text{wrt fg price}\end{array} * \begin{array}{l}\text{\% change fg}\\ \text{price from}\\ \text{baseline}_{t-1}\end{array}\right) + \left(\begin{array}{l}\text{elasticity of}\\ \text{fg acreage wrt}\\ \text{wheat price}\end{array} * \begin{array}{l}\text{\% change wheat}\\ \text{price from}\\ \text{baseline}_{t-1}\end{array}\right) + \left(\begin{array}{l}\text{elasticity of}\\ \text{fg acreage wrt}\\ \text{soybean price}\end{array} * \begin{array}{l}\text{\% change soybean}\\ \text{price from}\\ \text{baseline}_{t-1}\end{array}\right) + \left(\begin{array}{l}\text{elasticity of}\\ \text{fg acreage wrt}\\ \text{cotton price}\end{array} * \begin{array}{l}\text{\% change}\\ \text{cotton price}\\ \text{from baseline}_{t-1}\end{array}\right) \Bigg] + \left(1.0 - \begin{array}{l}\text{long run}\\ \text{adjustment}\\ \text{factor}\end{array}\right) * \left(\begin{array}{l}\text{calculated}\\ \text{fg}\\ \text{acreage}_{t-1}\end{array} - \begin{array}{l}\text{baseline}\\ \text{fg}\\ \text{acreage}_{t-1}\end{array}\right) \qquad (5)
$$

Equations similar to (5) are used to estimate harvested acreage for wheat, soybeans, and cotton. Lagged crop prices are used as expected price in the acreage equations. If the current years loan rate is greater than the previous year's crop price, the loan rate is used as the expected price in equation (5) for the calculation of harvested acreage. As will be seen in following sections, the loan rate also serves as the expected price if it is greater than lagged crop price in the yield and per acre variable production expense equations. This practice has been adopted because if loan rates exceed the previous year crop price the loan rate is the marginal value of output for planting and input use decisions. This feature allows the user to simulate the impacts of loan rates which exceed the expected market price on crop acreage, production and income.

Including the price of other crops in the harvested acreage equation (5) allows substitution of one crop for another in response to changes in relative prices. Assuming a homogeneous acreage response function of degree zero, an equal increase in the expected price of all crops and input prices should have no effect on the mix of crops grown; while a change in the expected price of only one crop would, of course, affect the crop mix. The elasticities used in the four acreage equations (5) approximate homogenity of degree zero (Table VII). The own acreage elasticity for feed grains is .10 in the short run and .15 in the long run while the cross elasticities with respect to wheat, soybeans, and cotton prices are -.03, -.06, and -.01, respectively (Table VII).

Acreage Set-Aside

Adjustments to acreage levels for simulating land diversion or set-aside are made before computing acreage response to change in relative crop prices. The procedure for accounting for set-aside is different from the normal calculation approach used by POLYSIM. If the general POLYSIM calculation approach were used, a mathematical formulation to account for changes in set-aside from the level assumed in the baseline would appear at the end of equation (5). However, farmer adjustment in acreage as a result of set-aside programs are made completely during the crop year. There is no multi-year distributed lag in crop acreage response to set-aside. Hence, if the set-aside computation were tacked onto equation (5) which includes a distributed lag structure, set-aside

TABLE VII

DIRECT AND CROSS ACREAGE, YIELD AND SUPPLY ELASTICITIES[1]

	Feed Grains $Price_{t-1}$	Wheat $Price_{t-1}$	Soybean $Price_{t-1}$	Cotton $Price_{t-1}$
Feed grains acreage	.10 (.15)	-.03 (-.045)	-.06 (-.09)	-.01 (-.015)
Wheat acreage	-.03 (-.06)	.10 (.20)	-.02 (-.04)	-.01 (-.02)
Soybean acreage	-.15 (-.187)	-.02 (.024)	.25 (.312)	-.03 (-.037)
Cotton acreage	-.05 (-.10)	-.01 (-.02)	-.10 (-.20)	.30 (.60)
Feed grain yield	.10 (.20)			
Wheat yield		.05 (.10)		
Soybean yield			.10 (.20)	
Cotton yield				.15 (.20)

Source: Appendix A, Section 3 of Ray and Richardson (1978).

[1]Long-run elasticities are in parentheses under the respective short-run elasticity.

announced in year t would effect acreage in year t+1 even though the government enacted no set-aside program for year t+1. To get around this problem, the baseline harvested acreage is modified so as to include the effect of the user specified level of set-aside. This acreage value becomes the "new" baseline acreage which is used in equation (5) to compute harvested acreage.

The computational procedure is to first add the set-aside that was assumed in the original baseline to the original baseline value of harvested acreage and then subtract the set-aside specified by the user. Historically, however, not all acreage declared as set-aside would have been harvested even without the set-aside program. Some acreage in flood prone areas, on unproductive hilltops or in fallow are designated as set-aside areas. This slippage, or lack of complete effectiveness of set-aside in reducing harvested acreage, is taken into account in the computations. The rate of slippage, or percent slippage converted to a decimal, is user controlled. Equation (6) demonstrates the procedure for modifying baseline feed grain harvested acreage for set-aside. Similar relationships are included for wheat and cotton.

$$\begin{aligned}\text{Calculated harvested acreage for } fg_t = {} & \text{Baseline harvested acreage for } fg_t + \left\{ \text{baseline acreage set-aside for } fg_t * \left(1.0 - \text{baseline fg slippage rate}_t\right)\right\} \\ & - \left\{ \text{user supplied acreage set-aside for } fg_t * \left(1.0 - \text{user supplied fg slippage rate}_t\right)\right\} \qquad (6)\end{aligned}$$

<u>Yield Per Harvested Acre</u>

Yield per harvested acre is measured in tons for feed grains, bushels for wheat and soybeans, and pounds of lint for cotton. Each crop yield is estimated by adjusting the baseline value for yield up or down, in response to differences in the expected crop price from the baseline price. If the expected price is higher than the baseline price, more inputs, such as fertilizer, will be applied per acre which will increase yield per harvested acre. The four yield equations are of the form shown in equation (7) for feed grain yield. Lagged crop price is used as the expected price. (When loan rate in t is greater than lagged crop price, the loan rate is used as the expected price.) The distributed lag adjustment coefficient is included in each equation to allow multi-period adjustment in yields to a price change.

$$\begin{aligned}\begin{matrix}\text{Simulated}\\ \text{fg yield}\\ \text{ton/acre}_t\end{matrix} &= \begin{matrix}\text{Baseline}\\ \text{fg yield}\\ \text{ton/acre}_t\end{matrix} * \left[1.0 + \begin{pmatrix}\text{elasticity of}\\ \text{fg yield wrt}\\ \text{fg price}\end{pmatrix} * \begin{pmatrix}\text{\% change fg}\\ \text{price from}\\ \text{baseline}_{t-1}\end{pmatrix}\right.\\ &\left. + \begin{pmatrix}\text{elasticity of fg}\\ \text{yield wrt cost}\\ \text{of production}\end{pmatrix} * \begin{pmatrix}\text{\% change in prices}\\ \text{paid for inputs}\\ \text{from baseline}_{t-1}\end{pmatrix}\right] + \begin{pmatrix}1.0 - \begin{matrix}\text{long run}\\ \text{adjustment}\\ \text{factor}\end{matrix}\end{pmatrix}\\ &* \begin{pmatrix}\begin{matrix}\text{calculated}\\ \text{yield}_{t-1}\end{matrix} - \begin{matrix}\text{baseline}\\ \text{yield}_{t-1}\end{matrix}\end{pmatrix}\end{aligned} \tag{7}$$

The baseline is developed assuming a specific rate of increase in input prices. By including the input price variable in the yield equation, the crop yields can respond to modifications of the inflation rate for inputs from the baseline rate of inflation. The default elasticity of yield with respect to the cost of production is -.10 for all four crops.

The default own yield elasticities for the crops in the model are in Table VII. The short run yield elasticity for feed grains is .10 and its long run elasticity is .20 (Table VII). For a detailed discussion of the source of these parameters, see Appendix A, Section 3 of Ray and Richardson (1978).

Production

Once harvested acreage and yield per harvested acre have been estimated, the total production for the crop is simply the product of the acreage and yield. For feed grains the equation for total production is (8).

$$\begin{matrix}\text{Simulated fg} & & \text{Simulated} & & \text{Simulated} \\ \text{production} & = & \text{fg acreage} & * & \text{fg yield} \\ \text{m. ton}_t & & \text{m. acres}_t & & \text{ton/acre}_t\end{matrix} \qquad (8)$$

The total production equation for wheat, soybeans, and cotton follow the same general form as equation (8).

Supply

The total supply of a particular crop is the sum of production, imports and stocks on hand at the beginning of the crop year. Total crop production comes from equation (8), imports are exogenous and the value of stocks on hand for time period t are the ending year stocks in time period t-1 or the carryin for period t. For feed grains the total supply equation is (9).

$$\begin{matrix}\text{Simulated} & & \text{Simulated fg} & & \text{Exogenous} & & \text{Carryin} \\ \text{fg supply} & = & \text{production} & + & \text{fg imports} & + & \text{of fg} \\ \text{m. tons t} & & \text{m. tons t} & & \text{m. tons t} & & \text{m. tons t}\end{matrix} \qquad (9)$$

The total supply for the other three crops in the model follow the same form as equation (9).

Crop Production Expense

The final set of equations in the crop production section of the model calculate the variable production expense per harvested acre. As the per unit prices of inputs increase, the cost of a given level of input useage per acre increases. Economic theory suggests that the quantity of inputs used per acre is inversely related to the price of the input and positively related to the price of the output. The variable expense per acre relationships allow for changes in per acre expense due to input response to changing crop prices as well as for the change in outlay per unit from changes in input price. The feed grain variable production expense equation (10) is typical of the equation used for all four crops in the model.

$$\begin{aligned}\begin{matrix}\text{Simulated fg}\\ \text{variable prod}\\ \text{expense/acre}_t\end{matrix} &= \begin{matrix}\text{Baseline fg}\\ \text{variable prod}\\ \text{expense/acre}_t\end{matrix} * \left[1.0 + \begin{pmatrix}\text{elasticity of fg}\\ \text{expense per acre}\\ \text{wrt fg price}\end{pmatrix} * \begin{pmatrix}\text{\% change fg}\\ \text{price from}\\ \text{baseline}_{t-1}\end{pmatrix} + \begin{pmatrix}\text{elasticity of fg}\\ \text{expense per acre}\\ \text{wrt prices paid}\end{pmatrix} * \begin{pmatrix}\text{\% change prices}\\ \text{paid from}\\ \text{baseline}_{t-1}\end{pmatrix}\right] \\ &+ \left(1.0 - \begin{matrix}\text{adjustment}\\ \text{coefficient}\end{matrix}\right) * \begin{pmatrix}\begin{matrix}\text{simulated fg}\\ \text{variable prod}\\ \text{expense/acre}_{t-1}\end{matrix} - \begin{matrix}\text{baseline fg}\\ \text{variable prod}\\ \text{expense/acre}_{t-1}\end{matrix}\end{pmatrix}\end{aligned} \tag{10}$$

The lagged crop prices are used as the expected prices for equation (10). (When loan rate t is greater than lagged crop price, the loan rate is used as the expected price.) A distributed lag adjustment coefficient is used in equation (10) to allow for multi-period adjustments to changes in prices.

The own elasticities of variable per acre production expense for the crops in POLYSIM are presented in Table VIII. The elasticity of crop expense per acre with respect to the prices paid index is also presented in Table VIII. The sources of these elasticities are discussed in Appendix A, Section 3, of Ray and Richardson (1978).

TABLE VIII

ELASTICITY OF VARIABLE PRODUCTION EXPENSE FOR MODEL CROPS[1]

Elasticity of variable production expense$_t$	Feed Grain Price$_t$	Wheat Price$_t$	Soybean Price$_t$	Cotton Price$_t$	Index of Prices Paid$_{t-1}$
Feed grains wrt	0.100 (0.225)				1.00 (1.50)
Wheat wrt		0.050 (0.150)			1.00 (1.50)
Soybeans wrt			0.100 (0.225)		1.00 (1.50)
Cotton wrt				0.150 (0.225)	1.00 (1.50)

Source: Appendix A, Section 3 of Ray and Richardson (1978).

[1]Long-run elasticities are in parentheses under the respective short-run elasticity.

Total variable production expense for each of the model crops is calculated as the product of the number of harvested acres and variables production expense per acre. The feed grain equation for total variable production expense (11) is typical of the four crop equations in the model.

$$\text{Simulated fg total variable prod expense}_t = \text{Simulated fg harvested acreage}_t * \text{Simulated fg variable prod expense/acre}_t \qquad (11)$$

<u>Crop Prices</u>

Following Wold (1960, 1964), POLYSIM uses a recursive interpretation of supply, price and demand determination for agricultural crops. As has been discussed in earlier sections, current year production is a function of previous year prices and applicable federal farm policy provisions. After the current year crop has been produced, supply is essentially perfectly inelastic. Current year price is determined by the intersection of the perfectly inelastic supply curve and the expected demand curve. The quantity demanded is then a function of the crop price.

If the estimated crop supply is the same as the baseline crop supply the estimated price will be the same as the baseline price. If, on the other hand, estimated supply varies from the baseline supply, that is, there is a shift in the perfectly inelastic supply curve, the baseline price must be adjusted to reflect the new intersection of the supply and expected demand curves. The adjustment to the baseline price is computed as the product of the percentage change in supply from the baseline level and the inverse of the demand elasticity or price flexibility for the crop.

The expected demand includes, of course, export demand as well as various domestic demands. In POLYSIM the baseline total demand is the expected demand. Given the prominance of sharp shifts in export demand in recent years, the price relationships are specified to allow the user to predetermine export demand and therefore shift the expected demand curve. Hence, a set of terms is included in the crop price equations to account for shifts in expected demand.

The feed grain price equation (12) is typical of the price equations for the model crops.

$$\begin{aligned}\begin{matrix}\text{Calculated}\\ \text{fg price}\\ \text{\$/ton}_t\end{matrix} = \begin{matrix}\text{Baseline}\\ \text{fg price}\\ \text{\$/ton}_t\end{matrix} * \Bigg[1.0 + \begin{matrix}\text{price flexi-}\\ \text{bility of}\\ \text{feed grains}\end{matrix} * \Bigg\{\Bigg(\begin{matrix}\text{simulated}\\ \text{feed grain}\\ \text{supply}_t\end{matrix} \\ - \begin{matrix}\text{baseline}\\ \text{feed grain}\\ \text{supply}_t\end{matrix}\Bigg) - \Bigg(\begin{matrix}\text{expected}\\ \text{feed grain}\\ \text{demand}_t\end{matrix} - \begin{matrix}\text{baseline}\\ \text{feed grain}\\ \text{demand}_t\end{matrix}\Bigg)\Bigg\} \div \begin{matrix}\text{baseline}\\ \text{feed grain}\\ \text{supply}_t\end{matrix}\Bigg\}\Bigg]\end{aligned} \tag{12}$$

Feed grain price is in \$ per ton units, wheat and soybeans are in \$ per bushel units, and cotton is in \$ per pound units. The default price flexibilities for the model crops are in Table IX.

The estimated per bushel prices for the separate feed grains, corn, grain sorghum, barley and oats are computed from estimated feed grain price. Corn price is calculated by equation (13).

$$\begin{aligned}\begin{matrix}\text{Calculated}\\ \text{corn price}\\ \text{\$/bu.}_t\end{matrix} = \begin{matrix}\text{Calculated}\\ \text{fg price}\\ \text{\$/ton}_t\end{matrix} \div \Bigg[35.714 * \Bigg\{\begin{matrix}\text{percent of}\\ \text{corn in}\\ \text{feed grains}\end{matrix} + \Bigg(\begin{matrix}\text{percent of}\\ \text{grain sorghum}\\ \text{in feed grains}\end{matrix} \\ * \begin{matrix}\text{grain sorghum}\\ \text{nutrient equiva-}\\ \text{lence to corn}\end{matrix}\Bigg) + \Bigg(\begin{matrix}\text{percent of}\\ \text{barley in}\\ \text{feed grains}\end{matrix} * \begin{matrix}\text{barley nutrient}\\ \text{equivalence to}\\ \text{corn}\end{matrix}\Bigg) \\ + \Bigg(\begin{matrix}\text{percent of}\\ \text{oats in}\\ \text{feed grains}\end{matrix} * \begin{matrix}\text{oats nutrient}\\ \text{equivalence}\\ \text{to corn}\end{matrix}\Bigg)\Bigg\}\Bigg]\end{aligned} \tag{13}$$

TABLE IX

OWN PRICE FLEXIBILITY SCHEDULES FOR FEED GRAINS, WHEAT, SOYBEANS AND COTTON

Feed Grains	Own Price Flexibility
relative coverage[1] < 0.05	-6.00
0.05 ≥ relative coverage < 0.10	-4.00
0.10 ≥ relative coverage < 0.20	-3.50
0.20 ≥ relative coverage < 0.30	-2.00
0.30 ≥ relative coverage	-1.00
Wheat	
relative coverage < 0.10	-6.00
0.10 ≥ relative coverage < 0.15	-4.00
0.15 ≥ relative coverage < 0.20	-3.00
0.20 ≥ relative coverage < 0.30	-2.40
0.30 ≥ relative coverage < 0.50	-2.00
0.50 ≥ relative coverage < 0.60	-1.50
0.60 ≥ relative coverage	-1.00
Soybeans	
relative coverage < 0.033	-6.00
0.033 ≥ relative coverage < 0.066	-4.00
0.066 ≥ relative coverage < 0.100	-3.00
0.100 ≥ relative coverage < 0.150	-2.50
0.150 ≥ relative coverage < 0.200	-2.00
0.200 ≥ relative coverage	-1.75
Cotton	
relative coverage < 0.15	-5.00
0.15 ≥ relative coverage < 0.20	-4.00
0.20 ≥ relative coverage < 0.25	-3.00
0.25 ≥ relative coverage < 0.35	-2.25
0.35 ≥ relative coverage < 0.55	-1.75
0.55 ≥ relative coverage	-1.00

Source: Appendix A, Section 4 of Ray and Richardson (1978).

[1]Relative coverage is the expected ending year carryover expressed as a percent of expected total utilization. In the model,

$$\text{relative coverage} = \frac{\text{calculated supply}_t - (\text{baseline or expected demands}_t)}{\text{baseline or expected demands}_t}$$

so as the fraction gets small the ending year carryover is small relative to demands and vice versa.

To obtain equation (13), the relationship used by the USDA to compute feed grain price based on the prices, corn nutrient equivalences, the mix of the four separate grains was solved in terms of corn price. The constant 35.714 converts bushels to tons. The same proportional relationships between the baseline corn price and the baseline prices of grain sorghum, barley, and oats are used to compute the estimated prices for each of the minor feed grains. An equation similar to the oat price equation (14) is used to estimate the price for barley and grain sorghum.

$$\text{Calculated oat price } \$/\text{bu.}_t = \frac{\text{Baseline oat price } \$/\text{bu.}_t}{\text{Baseline corn price } \$/\text{bu.}_t} * \text{Calculated corn price } \$/\text{bu.}_t \qquad (14)$$

Generally the prices differ by the feeding value of oats, barley, and grain sorghum relative to corn.

Government Price Supports

Non-recourse Commodity Credit Corporation (CCC) loans and direct government grain purchases have been part of farm program legislation since the 1930's. At the user's option, POLYSIM will simulate the support of crop prices at levels specified by the user. (Coding the "Farm Policy Card" for activating price supports is described in the POLYSIM User's Manual (Richardson and Ray, 1975a).) The crop price is calculated as usual based on the prevailing supply and demand conditions by equation (12). Price support action is taken only if the estimated price is less than the support price or loan rate. When the market price is less than the support price (or loan rate), the model computes the quantity of grain of fiber that must be diverted from the market to raise the average market price to the loan rate.

A typical equation for computing the quantity of grain that must be put under CCC loan or diverted from the market to raise market price to the new wheat price, a weighted average of the loan rate and the initial calculated wheat market price, is illustrated in equation (15).

$$\begin{matrix}\text{Quantity of} \\ \text{wheat in CCC} \\ \text{loan program}\end{matrix} = \begin{matrix}\text{Calculated} \\ \text{supply of} \\ \text{wheat}_t\end{matrix} * \left[\left(1.0 - \frac{\text{New wheat price}_t}{\text{calculated wheat market price}_t}\right) \div \begin{matrix}\text{wheat own} \\ \text{price} \\ \text{flexibility}\end{matrix}\right] \quad (15)$$

The formulation in the inner parentheses computes the percentage increase in the market price that is required to reach the support price or loan rate. The percent increase in price (with sign changed) is divided by the price flexibility of demand for crop to compute the percent reduction in supply that would make the market clear at the higher market price. This computation is equivalent to multiplying the percent change in price times the overall elasticity of demand for the crop. Hence, the equation determines the length of movement up the demand curve or equivalently the leftward shift in the perfectly inelastic short run supply curve that would result in the market price being equal to the loan rate.[3] The calculated reduction in supply is the quantity of stocks

[3]The program can be easily modified so market price is increased to user specified percentage of the support rate based on an assumed participation rate. A substitute set of subroutines are also available that estimates quantities in CCC loan, quantities redeemed and quantities added to government stock. Variable length of CCC loans are allowed with this approach. An application of this set of computations can be found in (Ericksen, Ray, and Richardson, 1976).

that must be diverted from the market. The market price is set equal to the support price and the model proceeds to the crop demands section.

The CCC has always had some provision for releasing accumulated stocks in the market when the average market price exceeded the loan rate by a certain percentage. In the model, CCC loans are released to the market when the average market price, calculated by equation (12), is 50 percent greater than the loan rate. Stocks owned by the CCC are released to the market when market price exceeds loan rates by 75 percent. (Other release policies have been programmed by user specified options and are described in the POLYSIM User's Manual (Richardson and Ray, 1975a).) The quantity of stocks released by the CCC are calculated by equation (16).

$$\text{Quantity of wheat stocks to release from CCC stocks}_t = \text{Calculated wheat supply}_t * \left[\left(1.0 - \frac{\text{wheat release price}_t}{\text{calculated wheat market price}_t}\right) \div \text{wheat own price flexibility}\right] \quad (16)$$

Equation (16) calculates the amount of stocks that the CCC can release without lowering the average market price below the release price. The average market price for the crop is set equal to the release price and the quantity of stocks held by the CCC in loan or owned are reduced by the amount of the stock release. The model then proceeds to the domestic demand equations with the revised market price for the particular crop.

The costs to the Commodity Credit Corporation for holding stocks of grains and cotton are calculated by the model. The total costs for holding government owned stocks include the interest charge for the average value of stocks held, the in and out charge for entering the market, the storage cost for physical storage of a commodity, and the net profit or loss from the release of stocks. The total costs to the government for holding CCC loans is zero since the farmer who owns the commodity pays the storage costs, the in and out charge, the interest and stands to make a profit or loss.

Crop Demands

As indicated earlier the structure of agricultural crop supply, price and demand tend to be recursive in nature. Ceteris paribus, supply is a function of previous year price, price is determined by the level of supply relative to expected demand and actual quantity demanded is a function of price (and other variables). Hence a simplified causation diagram would appear as:

$$\text{Price}_{t-1} \longrightarrow \text{Quantity Supplied}_t \longrightarrow \text{Price}_t \longrightarrow \text{Quantity Demanded}_t$$

In general, the domestic and export crop demand equations use changes in current year price from the baseline price and elasticities of demand to compute new quantities demanded. In the equations that follow this approach, it is assumed that demand shifters (population, per capita incomes, etc.) are unchanged from those implicit in the baseline demand quantities.

However, in the case of livestock feed demands, the price of livestock, substitute feed prices and other demand shifters determined within the agricultural economy do not necessarily remain at levels implicit in the baseline. Hence, the various livestock feed demand relationships are structured to include the impact of changes in demand shifters as well as the feed's own price. These relationships for estimating livestock feed demands are presented first. The domestic and export demand relationships which assume no changes in the demand shifters from the baseline follow the subsections on feed demand.

Feed Grain Feed Demands

The domestic demand for feed grains and by-products (protein) as livestock feed are calculated as a derived demand based on livestock production, livestock prices and the price of feed grains and soybean meal. The procedure is a multi-step method that is repeated for each of the seven livestock categories in the model and results in values for feed grains demanded by each livestock group. The equations follow the structure reported by Richardson and Ray (1977).

The five equations used to estimate feed grain demand for hogs are presented here to illustrate the procedure. The first step is to calculate the concentrate feed conversion rate, defined as the pounds of concentrates fed per pound of liveweight production.[4] The baseline concentrate feed conversion rate (equation 17) is adjusted up or down depending upon

[4]Concentrates fed to livestock and poultry includes corn, sorghum, barley, oats, wheat, rye, oilseed meal, animal protein feeds, and other by-product feeds. For POLYSIM, wheat has been subtracted out of concentrates feed and is treated as a separate domestic demand for wheat.

changes in the own livestock price and the price of feed grains and soybean meal.[5]

$$\begin{aligned}\begin{pmatrix}\text{Calculated concen-}\\ \text{trate feed conver-}\\ \text{sion rate for hogs}_t\end{pmatrix} &= \begin{pmatrix}\text{Baseline feed}\\ \text{conversion}\\ \text{rate for hogs}_t\end{pmatrix} * \Bigg[1.0 + \begin{pmatrix}\text{elasticity of feed}\\ \text{conversion rate}\\ \text{wrt hog price}\end{pmatrix}\\ &* \begin{pmatrix}\text{\% change hog}\\ \text{price from}\\ \text{baseline}_t\end{pmatrix} + \begin{pmatrix}\text{elasticity of feed}\\ \text{conversion rate}\\ \text{wrt fg price}\end{pmatrix} * \begin{pmatrix}\text{\% change fg}\\ \text{price from}\\ \text{baseline}_t\end{pmatrix}\Bigg]\end{aligned} \quad (17)$$

If the simulated price of hogs is higher than the baseline value, the concentrate feed conversion rate will increase whereas if the feed grain or soybean meal prices are higher than their baseline value the feed conversion rate will decrease. The price elasticities of feed conversion rates for the livestock categories (17) in POLYSIM are presented in Table X.

The second step is to compute the quantity of concentrates demanded that is consistent with the calculated feed conversion rates and the calculated livestock production. Multiplying the concentrate feed conversion rate (pounds of feed per pound of production) by the calculated livestock production (millions of pounds) results in the total concentrates demanded by each livestock category. The total concentrates

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[5]Soybean meal price is estimated in the model by the following equation:

$$PSM_t = -27.5326 + 5.9245\ PSB_t + 0.6597\ PCM_t + 0.5484\ LSPU_t$$

Student t	2.00	4.12	3.46
Elasticity	0.208	0.617	0.473

$F = 250.8 \quad R^2 = 0.98 \quad S.E. = 5.83 \quad D = 2.17 \quad \bar{Y} = 80.4$

where: PSM is price of soybean meal ($/ton), PSB is price of soybeans ($/bu.), PCM is price of cottonseed meal ($/ton) and LSPU is number of livestock production units (millions), for years 1950-1974, less 1972.

TABLE X

ELASTICITY OF CONCENTRATE FEED CONVERSION RATE AND ELASTICITY OF PERCENT OF FEED GRAINS IN CONCENTRATES FED FOR EACH OF THE LIVESTOCK CATEGORIES IN THE MODEL

Elasticity of feed Conversion $Ratio_t$ for:	Own Livestock $Price_t$	Feed Grain $Price_t$	Soybean Meal $Price_t$
Cattle and Calves wrt	0.894	-0.834	
Hogs wrt	0.132	-0.051	
Sheep and Lambs wrt	0.566	-0.222	
Chickens wrt	0.180	-0.180	
Turkeys wrt	0.197	-0.069	
Eggs wrt	0.153	-0.122	0.069
Milk wrt	0.080	-0.080	
Elasticity of Percent of Feed Grains in Concentrates Fed_t for:	**Own Livestock $Price_t$**	**Feed Grain $Price_t$**	**Soybean Meal $Price_t$**
Cattle and Calves wrt		-0.114	0.087
Hogs wrt	-0.099	-0.092	0.071
Sheep and Lambs wrt	-0.230	-0.009	0.220
Chickens wrt	-0.133	-0.002	0.037
Turkeys wrt	-0.097	-0.099	0.118
Eggs wrt	-0.007	-0.106	
Milk wrt	-0.005	-0.078	0.042

Source: Appendix A, Section 5 of Ray and Richardson (1978).

equation for hogs (18) is typical for the other meat animal categories and differs from the milk and egg equations in that meat production is in carcass weight and must be converted to a liveweight basis.

$$\text{Calculated total concentrates fed to hogs m. tons}_t = \left\{ \left(\text{Calculated hog production m. lbs. carcass wt.}_t \div \begin{matrix}\text{Factor to convert} \\ \text{hog carcass wt.} \\ \text{to liveweight}\end{matrix} \right) * \begin{matrix}\text{Calculated feed} \\ \text{conversion rate} \\ \text{for hogs}_t\end{matrix} \right\} \div 2000.0 \tag{18}$$

The total concentrates demanded in (18) is a function of own and cross livestock prices lagged one period in the production equations, current own livestock prices in the feed conversion rate, as well as, the current prices of feed grains and soybean meal. Hence, the underlying relationships cause total concentrates demanded to be a derived demand of the livestock industry.

The third step is to estimate the percent of feed grains in the concentrates fed for each of the livestock groups. This set of seven equations is typified by equation (19) for hogs.

$$\begin{matrix}\text{Calculated percent of} \\ \text{fg in concentrates} \\ \text{fed to hogs}_t\end{matrix} = \begin{matrix}\text{Baseline percent of} \\ \text{fg in concentrates} \\ \text{fed to hogs}_t\end{matrix} * \left[1.0 + \left(\begin{matrix}\text{elasticity of \% fg} \\ \text{concentrates fed to} \\ \text{hogs wrt hog price}_t\end{matrix} * \begin{matrix}\text{\% change hog} \\ \text{price from} \\ \text{baseline}_t\end{matrix} \right) + \left(\begin{matrix}\text{elasticity of \% fg} \\ \text{in concentrates fed to} \\ \text{hogs wrt fg price}_t\end{matrix} * \begin{matrix}\text{\% change fg} \\ \text{price from} \\ \text{baseline}_t\end{matrix} \right) \right] \tag{19}$$

The amount of feed grains in concentrates fed, as a percentage, increases as the own livestock price increases but decreases when the feed grain price increases. The default elasticities used in equation (19) for the separate livestock categories are presented in Table X.

The final step is to separate total concentrates demanded by each livestock category into feed grains and by-product feeds (high protein). This is handled by equations similar to (20) and (21) for each of the livestock categories. Equation (20) computes the derived demand for feed grains by hogs by multiplying the calculated total concentrates fed to hogs by the percent of feed grains in concentrates fed to hogs.

$$\text{Calculated fg demanded by hogs m. tons}_t = \text{Calculated total concentrates fed to hogs m. tons}_t * \text{Calculated percent of fg in concentrates fed to hogs}_t \quad (20)$$

Feed grain demand is estimated for each livestock category in the same manner. Total feed grain feed demand is computed as the sum of the calculated feed grain demands in equation (19) over the seven livestock categories. The resulting feed grain demand is a derived demand for feed grains based on the livestock production and the simulated livestock and feed prices.

By-Product Feed Demands

The total by-product demand for each livestock category is calculated by equation (21); it is simply the difference between total concentrates demanded and feed grains demanded.[6] Since the equation is similar for all livestock categories the equation for hogs is presented here.

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[6]By-product feeds include high protein feeds, animal proteins, grain protein feeds, and other by-product feeds. High protein feeds are oilseed meal, such as soybean meal and cottonseed meal. Animal proteins are meat, fish, and milk by-products and grain protein feeds are by-product of millers and distillers.

$$\begin{matrix}\text{Calculated by-}\\\text{product demand}\\\text{by hogs m. tons}_t\end{matrix} = \begin{matrix}\text{Calculated total}\\\text{concentrates fed}\\\text{to hogs m. tons}_t\end{matrix} * \left(1.0 - \begin{matrix}\text{Calculated \% of fg}\\\text{in concentrates}\\\text{fed to hogs}_t\end{matrix}\right) \quad (21)$$

The total by-product demand is the sum of the individual livestock categories' demand, computed by equation (21).

Domestic Demands for Other Model Crops

Wheat, soybeans, and cotton domestic demands consist of the following: wheat food demand, wheat feed demand, soybean mill demand and cotton mill demand. Other domestic demand for each of the four crops (seed demand, residual, etc.) are considered exogenous.

The domestic food demand of wheat is a function of wheat price and demand shifters, such as the level and distribution of disposable income and population. The influence of the demand shifter variables are embodied in the baseline domestic wheat food demand level. Changes in domestic farm policy will not significantly effect the level of population or values of other demand shifter variables. Hence, only the impact of a change in the price of wheat resulting from a change in policy or different yield and export projections are of importance. The domestic wheat food demand (22) is estimated as a deviation away from the baseline value resulting from changes in wheat price from its baseline.

$$\begin{matrix}\text{Calculated domestic}\\\text{wheat food demand}\\\text{m. bu.}_t\end{matrix} = \begin{matrix}\text{Baseline domestic}\\\text{wheat food demand}\\\text{m. bu.}_t\end{matrix} * \left[1.0 + \left(\begin{matrix}\text{elasticity of}\\\text{wheat food demand}\\\text{wrt own price}\end{matrix}\right) * \left(\begin{matrix}\text{\% change of}\\\text{wheat price}\\\text{from baseline}_t\end{matrix}\right)\right] + \left(1.0 - \begin{matrix}\text{long run}\\\text{adjustment}\\\text{factor}\end{matrix}\right) - \left(\begin{matrix}\text{calculated}\\\text{wheat food}\\\text{demand}_{t-1}\end{matrix} - \begin{matrix}\text{baseline}\\\text{wheat food}\\\text{demand}_{t-1}\end{matrix}\right) \quad (22)$$

The distributed lag adjustment coefficient is included in (22) to allow domestic wheat food demand to have a multi-period adjustment to changes in wheat price. The default elasticities of wheat food demand with respect to own price are -.10 in the short run and -0.20 in the long run (Table XI).

Wheat Feed Demand. The domestic demand for wheat as livestock feed is a function of wheat price and feed grain price. When the price of wheat gets close to the price of corn wheat will be substituted for corn at the margin. Wheat feed demand is estimated with equation (23).

$$\begin{aligned}\text{Calculated wheat feed demand m. bu.}_t &= \text{Baseline wheat feed demand m. bu.}_t * \Bigg[1.0 + \begin{pmatrix}\text{elasticity of}\\ \text{wheat feed demand}\\ \text{wrt own price}\end{pmatrix} * \begin{pmatrix}\text{\% change in}\\ \text{wheat price}\\ \text{from baseline}_t\end{pmatrix} + \begin{pmatrix}\text{elasticity of}\\ \text{wheat feed demand}\\ \text{wrt fg price}\end{pmatrix} * \begin{pmatrix}\text{\% change in}\\ \text{fg price from}\\ \text{baseline}_t\end{pmatrix}\Bigg] \\ &+ \begin{pmatrix}1.0 - \text{long run adjustment factor}\end{pmatrix} * \begin{pmatrix}\text{calculated wheat feed demand}_{t-1} - \text{baseline wheat feed demand}_{t-1}\end{pmatrix}\end{aligned} \quad (23)$$

A downward adjustment in feed grains fed to livestock, based on wheat's feeding equivalent relative to corn, is made whenever the wheat price gets within 12 percent of corn price. (On a corn equivalent feed unit basis wheat is 12 percent more valuable as a livestock feed than corn.)

Soybean Mill Demand. Soybean domestic mill demand is a function of the price of soybeans, the number of grain consuming livestock production units, mill capacities, prices of substitute protein sources and vegetable oils, population, and disposable incomes. All of these factors influencing demand are embodied in the baseline value for soybean mill demand. In a farm policy analysis where the demand shifters such as

TABLE XI

DOMESTIC AND EXPORT DEMAND ELASTICITIES FOR THE MODEL CROPS[1]

	Feed Grain $Price_t$	Wheat $Price_t$	Soybean $Price_t$	Cotton $Price_t$
Wheat Domestic				
Food $Demand_t$ wrt		-0.100 (-0.200)		
Feed $Demand_t$ wrt		-0.300 (-0.600)		
Soybean Domestic				
Mill $Demand_t$ wrt			-0.350 (-0.700)	
Cotton Domestic				
Mill $Demand_t$ wrt				-0.100 (-0.150)
Feed grain export $demand_t$ wrt	-0.500 (-1.500)			
Wheat export $demand_t$ wrt		-0.500 (-1.500)		
Soybean export $demand_t$ wrt			-0.650 (-1.950)	
Cotton export $demand_t$ wrt				-0.500 (-1.500)

Source: Appendix A, Section 4 of Ray and Richardson (1978).

[1]Long-run elasticities are in parentheses under the respective short-run elasticity.

income, population, and mill capacity are not altered, changes in mill demand for soybeans from its base value are largely dependent on soybean price and the level of livestock production. The soybean mill demand equation in POLYSIM allows the baseline soybean mill demand, as specified in equation (24) to respond to soybean price and the number of livestock production units.

$$\text{Calculated soybean mill demand m. bu.}_t = \text{Baseline soybean mill demand m. bu.}_t * \left[1.0 + \left(\text{elasticity of soybean mill demand wrt own price}\right) * \left(\text{\% change in soybean price from baseline}_t\right) + \left(\text{elasticity of soybean mill demand wrt no. of livestock production units}\right) * \left(\text{\% change in no. of livestock production units from baseline}_t\right)\right] + \left(1.0 - \text{long run adjustment factor}\right) * \left(\text{calculated soybean mill demand m. bu.}_{t-1} - \text{baseline soybean mill demand m. bu.}_{t-1}\right) \tag{24}$$

The distributed lag adjustment factor is included in (24) to allow the domestic soybean mill demand to have a multi-period adjustment to changes in soybean price. The demand elasticities for (24) are presented in Table XI.

<u>Cotton Mill Demand</u>. Cotton domestic demand is made up entirely of mill demand. Mill demand for cotton is a function of cotton price, disposable incomes, population and the price of synthetic fibers. The baseline value for mill demand embodies all of these factors and, since farm policy only influences cotton price to any great degree, changes in mill demand from its baseline value are largely a function of cotton price.

The cotton mill demand equation (25) adjusts the baseline cotton mill demand up or down as cotton price varies its baseline value.

$$\begin{aligned}\begin{matrix}\text{Calculated cotton}\\ \text{mill demand}\\ \text{m. net bales}_t\end{matrix} &= \begin{matrix}\text{Baseline cotton}\\ \text{mill demand}\\ \text{m. net bales}_t\end{matrix} * \left[1.0 + \begin{pmatrix}\text{elasticity of cotton}\\ \text{mill demand wrt}\\ \text{own price}\end{pmatrix}\right. \\ &\left. * \begin{pmatrix}\text{\% change in}\\ \text{cotton price}\\ \text{from baseline}_t\end{pmatrix}\right] + \begin{pmatrix}1.0 - \begin{matrix}\text{long run}\\ \text{adjustment}\\ \text{factor}\end{matrix}\end{pmatrix} * \begin{pmatrix}\begin{matrix}\text{calculated}\\ \text{cotton mill}\\ \text{demand}_{t-1}\end{matrix} - \begin{matrix}\text{baseline}\\ \text{cotton mill}\\ \text{demand}_{t-1}\end{matrix}\end{pmatrix}\end{aligned} \tag{25}$$

The distributed lag factor in (25) allows the cotton mill demand to have multi-period adjustments to changes in cotton price. The default elasticity of demand for cotton at the mill wrt own price is -0.10 (Table XI).

Total domestic demands are calculated for each of the model crops (feed grains, wheat, soybeans, and cotton) as the sum of the endogenous demands and an exogenous other demand component. Total feed grain domestic demand is the sum of domestic feed demand and feed grains used for other than feed uses (food, seed and industrial). Wheat domestic demand is the sum of domestic food and feed demand and the exogenous component of seed and industrial uses. Soybean total domestic utilization is the sum of mill demand for crushing and the exogenous demand for seed. Cotton total domestic demand consists only of domestic mill consumption.

Export Demands

Foreign demands for feed grains, wheat, soybeans, and cotton are dependent upon the domestic price, the foreign supply, population and income of importing countries and other variables. The baseline values for crop exports are developed with specific assumptions pertaining to these variables. When a farm policy is analyzed which changes only the domestic prices, it can be modeled by adjusting the baseline export value for changes in the price from the baseline. However, if the base assumptions pertaining to foreign supply are changed, the analyst can provide a new export value that has been determined outside the system. The prespecified export value is used as the calculated value from exports and the model computes the crop's price, taking into account the shift in the demand curve.

The feed grain export equation (26) typifies the export equations used for each of the four crops.

$$\begin{aligned} \text{Calculated fg export m. tons}_t &= \text{Baseline fg export m. tons}_t * \left[1.0 + \left(\text{elasticity of fg export wrt own price} * \text{\% change fg price from baseline}_t\right)\right] \\ &+ \left(1.0 - \text{long run adjustment factor}\right) * \left(\text{calculated fg export}_{t-1} - \text{baseline fg export}_{t-1}\right) \end{aligned} \tag{26}$$

The distributed lag adjustment coefficient in (26) allows crop exports to have a multi-year response to changes in price. The export price elasticities for feed grains are reported in Table XI along with the export elasticities for wheat, soybeans, and cotton.

Total Utilization and Carryovers

For each crop the model calculates the total utilization for each time period as the sum of total domestic demands and export demands. Total carryover or ending year stocks is the difference between total supply and total utilization plus government stocks.

Accounting Identities

Crop and livestock cash receipts and the expenses for producing crops and livestock are simulated with a series of identity relationships.

Also, identities are used to compute totals for production expenses, government payments and aggregate farm income.

Crop Cash Receipts

Simulated cash receipts for each crop and livestock category are computed by adjusting the baseline cash receipts for the commodity for changes in price and production. Cash receipts are not generally equal to price times production (value of production). Farmers do not market all of the annual production of grain. Crop and livestock farmers feed part or all of their home-grown to their livestock. Changes in farmer stored grain also influence the amount of grain sold for cash. In estimating cash receipts, the proportion of production sold for cash is implicitly assumed to be the same as in the baseline. The feed grain cash receipts equation (27) is typical of the equations used for the four crops in the model.

$$\text{Simulated fg cash receipts m. }\$_t = \left\{\left(\frac{\text{simulated fg price}_t}{\text{baseline fg price}_t} * \frac{\text{simulated fg production}_t}{\text{baseline fg production}_t} * \text{baseline fg cash receipts}_t\right) * 0.35\right\} + \left\{\left(\frac{\text{simulated fg price}_{t-1}}{\text{baseline fg price}_{t-1}} * \frac{\text{simulated fg production}_{t-1}}{\text{baseline fg production}_{t-1}} * \text{baseline fg cash receipts}_{t-1}\right) * 0.65\right\} \qquad (27)$$

The parameters 0.35 and 0.65 in (27) are weights to convert crop year cash receipts for feed grains to a calendar year basis. The default parameters for converting to wheat cash receipts to a calendar year are 0.65 and 0.35. The parameters for soybeans are 0.35 and 0.65 and 0.55 and 0.45 for cotton. The parameter values were suggested by the Farm

Income Group, NEAD, USDA, and can be changed by the user in the UPDATE program (Richardson and Ray, 1975b). As can be seen in equation (27), the baseline cash receipts are adjusted by the ratio of the simulated and baseline prices and the ratio of the simulated and baseline production levels. If there are no changes in price or production, the ratios reduce to ones and cash receipts are unchanged from the baseline.

Total cash receipts for all crops is computed as the sum of simulated cash receipts for the four major crops (feed grains, wheat, soybeans, and cotton), plus cash receipts for non-model crops. Since cash receipts for non-model crops are exogenous in the model, the baseline value is used in all analyses unless side calculations have indicated the new level for the variable, then it is read in as data.

Livestock Cash Receipts

Cash receipts for each of the seven livestock categories are estimated by adjusting the baseline cash receipts for proportional changes in the estimated price and production relative to their respective baseline values. The cash receipts for each livestock category are estimated with an equation similar to the following equation (28) for hogs:

$$\text{Simulated hog cash receipts m. \$}_t = \text{Baseline cash receipts for hogs}_t * \frac{\text{Simulated hog price}_t}{\text{Baseline hog price}_t} * \frac{\text{Simulated hog production}_t}{\text{Baseline hog production}_t} \qquad (28)$$

Livestock production and price levels are simulated on a calendar year basis so no marketing year to calendar conversion is required for livestock cash receipts.

Cash receipts for livestock other than the seven major categories are exogenous. Total cash receipts for all livestock is the sum of the estimated cash receipts for the seven livestock categories plus the exogenous cash receipts for other livestock.

Total cash receipts for crops and livestock is the sum of cash receipts for all crops and all livestock. Total cash receipts are on a calendar year basis and reflect the changes in prices and production of the endogenous crops and livestock categories from their baseline values. To simulate total realized gross farm income, values are needed for the value of non-money income and government payments.

Realized Non-Money Income

The baseline value of home consumption of each livestock category is adjusted for changes in the price of the commodity. The equation for the value of home consumption of hogs (29) is similar to those used for the other livestock categories.

$$\text{Simulated value of home consumption for hogs}_t = \text{Baseline value of home consumption for hogs}_t * \frac{\text{Simulated hog price}_t}{\text{Baseline hog price}_t} \quad (29)$$

It is assumed that the quantity of each type of livestock consumed on the farm is constant and only its value changes with a change in price. In reality, some change in quantity consumed would also occur with a price change. Since the demand for livestock products consumed on the farm is probably highly inelastic, the assumption is not very restrictive.

Perquisites other than livestock consumed on the farm (rental value of dwellings, crops, firewood, and other income) is exogenous. Total realized non-money income is the sum of the value of home consumption for each of the major livestock categories plus the value of other farm perquisites.

Government Payments

Payments for acreage set-aside and deficiency payments, when applicable, are computed separately for each of the model crops. Set-aside payments are calculated for feed grains, wheat, and cotton with relationships similar to equation (30); which is presented in terms of feed grains.

$$\text{Simulated fg set-aside payments m. tons}_t = \text{Set-aside acreage for fg m. ac.}_t * \text{Set-aside payment per acre for fg \$/ac.}_t \qquad (30)$$

The set-aside levels and payment rates default to baseline levels unless specified by the user. Per acre payment rates may be zero, if set-aside is required for eligibility for other provisions in farm legislation.

Deficiency payments are income support payments paid to farmers and originated with the Agricultural Consumer Protection Act of 1973 and are provided for in the Food and Agricultural Act of 1977. Payments are made only when the average crop price (for the first five months of the marketing year) is less than the target price. Deficiency payments are calculated by the model for corn, grain sorghum, barley, wheat and cotton.

The procedure for determining the deficiency payment for each of the five crops is similar and is presented here for the case of corn. The first step is to determine the deficiency payment rate. By law, the payment rate is the lesser value of 1) the difference between target price and average market price, and, 2) the difference between target price and loan rate (31).

$$\text{Corn deficiency payment rate}_t = \underline{\text{The Lesser Of}} \begin{cases} \text{Corn target price}_t - \text{Corn average market price}_t \\ \text{OR} \\ \text{Corn target price}_t - \text{Corn loan rate}_t \end{cases} \quad (31)$$

The total deficiency payment is the product of the deficiency payment rate, the program acreage, the farm program yield, and the fraction of farmers participating in the program (32).

$$\text{Corn deficiency payment}_t = \text{Corn deficiency payment rate}_t * \text{Corn program acreage}_t * \text{Corn farm program yield}_t * \text{Fraction of corn farmers in program}_t \quad (32)$$

The baseline values for target price, loan rate, program acreage, farm program yield, and fraction of farmers in the program are used in (32) to determine deficiency payments unless the user provides alternative values. Deficiency payments for corn, grain sorghum, barley, wheat and cotton are summed to obtain total government deficiency payments paid to farmers.

To accurately simulate the deficiency payment provision in the Food and Agricultural Act of 1977, the model explicitly considers the specified target prices for corn, grain sorghum, barley, wheat, and cotton for 1978 and a procedure for adjusting these values over time, based on changes in the variable cost of production (or total production costs excluding land and general overhead costs). The procedure is the same for all crops in the model and is demonstrated here for corn (33).

$$\text{Corn target price}_t = \text{Corn target price}_{t-1} + \text{Variable cost of production}_{t-1} - \text{Variable cost of production}_{t-2} \quad (33)$$

As indicated by equation (33), the target price is increased over the previous years level if there is an increase in the variable cost of production.

Aggregate Production Expenses

Total variable production expense for the individual model crops (feed grains, wheat, soybeans, and cotton) is calculated by equation (11), which was presented earlier. Total variable production expense for the model crops is the sum of the expense levels for the four crops.

The total variable production expense for producing livestock is calculated as the sum of feed and non-feed variable costs. Feed costs are disaggregated into the following feed types: protein feed grains, wheat, and roughage. Protein feed costs are calculated in equation (34) based on by-product feeds fed to all livestock which was computed earlier in the model.

$$\text{Protein feed costs to livestock}_t = \text{Simulated by-product feed demands}_t * \text{Soybean meal price}_t \quad (34)$$

In assigning a cost to the livestock sector for protein feed, all by-product feeds (soybean meal, cottonseed meal, animal proteins, grain protein feeds and other by-product feeds) are costed out using the price of soybean meal.

Feed grain feed cost for producing all livestock is the cost of feed grains fed to livestock on the farm where it is grown plus the cost of feed grains purchased and fed to livestock (35).

$$\text{Fg feed costs to livestock}_t = \left\{ \text{calculated fg fed to livestock}_t * \text{fraction of fg sold}_t * \text{price of feed grains}_t \right\} + \left\{ \text{calculated fg fed to livestock}_t * \left(1.0 - \text{fraction of fg sold}_t \right) * \frac{\text{fg variable cost of production}_t}{\text{fg yield per acre}_t} \right\} \quad (35)$$

The portion of feed grains fed to livestock on the farm where it is raised is valued at its variable production cost per bushel while the portion that is purchased and then fed to livestock is valued at the average market price. The user may reprogram to value home-grown grain to include a portion of fixed costs by increasing variable cost by a specified percentage, say 25 percent.

The cost of wheat fed to all livestock categories is the market value of wheat times the quantity of wheat fed to livestock (36).

$$\text{Wheat feed costs to livestock}_t = \text{Calculated wheat fed to livestock}_t * \text{Calculated average wheat price}_t \quad (36)$$

It is assumed that all wheat fed to livestock is purchased in the market. Hence, the wheat feed costs are not separated into two costing components.

Total roughage cost for all livestock production is computed as the sum of the cost of roughage fed to livestock on the farm where it is grown and the cost of roughage purchased and fed to livestock (37).

$$\text{Roughage feed costs for livestock}_t = \left\{ \text{roughage fed to livestock}_t * \text{fraction of roughage purchased}_t * \text{price of hay}_t \right\}$$
$$+ \left\{ \text{roughage fed to livestock}_t * \left(1.0 - \text{fraction of roughage purchased}_t\right) * \text{variable production cost of roughage}_t \right\} \quad (37)$$

The portion of roughage that is purchased is costed out to the livestock sector at the market price for hay. The portion fed to livestock on the farm where it is grown is valued at the variable cost of producing hay.

Non-feed variable production expenses for livestock include salt, mineral supplements, and veterinarian expenses. As the price of livestock increases and the marginal value product of livestock output increases, farmers are willing to spend more for non-feed costs. The non-feed cost in terms of dollar per unit is computed for each livestock category by relationships similar to equation (38), which is demonstrated here for hogs.

$$\text{Simulated non-feed cost of hog production}_t = \text{Baseline non-feed cost of hog production}_t * \left[1.0 + \left(\text{elasticity of non-feed cost for hogs wrt own price} * \text{\% change in hog price from baseline}_t\right)\right] \quad (38)$$

The baseline non-feed cost (\$/unit of production) is adjusted slightly upward for increases in the own livestock price from its baseline level and slightly downward when the own livestock price is less then the baseline. The default non-feed expense per unit elasticities are presented in Table XII. Total non-feed costs for livestock production (39) is the sum of the seven livestock production levels times their respective non-feed costs per unit of production.

TABLE XII

ELASTICITY OF NON-FEED COSTS FOR LIVESTOCK PRODUCTION IN THE MODEL

Elasticity of Non-Feed Cost For	Own Livestock $Price_t$
Cattle and $Calves_t$ wrt	0.100
$Hogs_t$ wrt	0.020
Sheep and $Lambs_t$ wrt	0.005
$Chickens_t$ wrt	0.001
$Turkeys_t$ wrt	0.001
$Eggs_t$ wrt	0.001
Milk $Cows_t$ wrt	0.001

Source: Appendix A, Section 5 of Ray and Richardson (1978).

$$\begin{aligned}\text{Total non-feed costs for livestock}_t = &\left(\text{cattle and calf production}_t * \text{non-feed costs of cattle and calves}_t\right) + \left(\text{hog production}_t * \text{non-feed costs for hogs}_t\right) \\ &+ \left(\text{sheep production}_t * \text{non-feed costs of sheep}_t\right) + \left(\text{chicken production}_t * \text{non-feed costs for chickens}_t\right) \\ &+ \left(\text{turkey production}_t * \text{non-feed costs for turkeys}_t\right) + \left(\text{egg production}_t * \text{non-feed costs for eggs}_t\right) \\ &+ \left(\text{milk production}_t * \text{non-feed costs for milk}_t\right)\end{aligned} \quad (39)$$

Total variable production expenses for livestock production is the sum of feed grains feed costs, protein costs, roughage costs, and non-feed variable production costs.

Total variable production costs for model crops and livestock is the sum of total variable production costs for the four crops and the seven livestock categories, less double accounting of feed grains, soybeans, and wheat. "Double accounting" equations compute the portion of crop production expenses that was counted as feed expense for livestock. In the case of feed grains, the double counting adjustment is computed as the product of the variable production expense for producing a ton of feed grains and the tonnage of feed grains fed to livestock (equation (40)).

$$\text{Fg double accounting adjustment}_t = \frac{\text{Fg variable production expense per acre}_t}{\text{Yield per acre}_t} * \text{Fg fed to livestock}_t \quad (40)$$

The double accounting adjustment is calculated similarly for the other grain crops.

Total farm production expenses is the sum of variable production expenses for all model crops and livestock (adjusted for double accounting), the production costs of other livestock and crops not included in the model and total fixed costs of production. The total fixed costs and production expenses for other livestock and crops are exogenous to the model.

Aggregate Net Farm Income

Several measures of aggregate farm income and government payments are computed by the model. Total market and government receipts is the sum of total cash receipts for all crops and livestock and total government payments. Total government payments to farmers is the sum of set-aside payments for all crops, total deficiency payments for all model crops, and other direct government payments to farmers (wool growers, bee keepers, disaster payments, sugar program, etc.). Realized gross farm income is the sum of total market and government receipts and total realized non-money income. Realized net farm income is the difference between realized gross farm income and total farm production expenses.

CHAPTER IV

RESULTS OF USING CONTROL THEORY TO ANALYZE SELECTED FARM PROGRAMS

Farm Programs Selected for Analysis

Four farm programs are analyzed using the Control Theory Option in POLYSIM, to demonstrate the use of the technique for selecting values of particular farm policy variables. The farm programs analyzed are the following: No. 1 a price and income support program, No. 2 a price and income support program with voluntary acreage set-aside, No. 3 a price support and acreage set-aside program with a grain reserve provision, and No. 4 a price and income support program with voluntary acreage set-aside and increased export demands for feed grains, wheat and cotton during the first year simulated. Each farm program is analyzed for the four year period of 1978-1981. A four year horizon is used because farm programs are usually written for a four year period. And the additional computer costs associated with adding more years to the problem become restrictive.

Farm program No. 1, a price and income support program, guarantees feed grain, wheat and cotton farmers a minimum price they will receive for their products and a minimum income they will receive for their elegible production. The loan rate is the mechanism used to establish the minimum price participating farmers will receive. If production is sufficiently large to cause average prices to fall below the loan rate the Commodity Credit Corporation (CCC) is authorized to make loans to farmers, using their crops, valued at the loan rate, as collateral. In the event that prices continue to be low, the farmer can turn the collateral over to the CCC and the loan is considered paid. The income support is a direct payment to farmers, in the form of a deficiency payment, to make up the difference between the price participating farmers get for their crops in the market and the target price established in the farm program. The deficiency payment is paid according to the formula described in Chapter III. For program No. 1, the control mechanism selects values for the loan rates and target prices of feed grains, wheat and cotton that maximize the performance measure in Table IV. The loan rates and target prices must be contained within the upper and lower boundary constraints for these controls (Tables I and II).

Farm programs No. 2 and 4 have the price and income support provisions found in program No. 1 and in addition have an acreage set-aside provision. Acreage set-aside programs usually require that participating farmers divert a percent of their land to soil conserving uses. Farmers complying with the voluntary acreage set-aside requirements are then eligible for price and income supports, as well as, a payment for diverting the land. A non-zero payment rate for acreage set-aside is used to insure participation in the programs. The control mechanism selects acreage set-aside levels and loan rates for feed grains, wheat and cotton that maximize the performance measure in Table IV. The loan rates and acreage set-aside levels must be within the upper and lower boundary constraints for these control variables (Tables I and III). Target price levels approved for the 1977 Agricultural Act are used as the target prices in programs No. 2 and No. 4, for the income support provision.

Based on the projections of commodity analysts in the USDA, the ending year carryovers of feed grains, wheat and cotton are expected to increase annually over the next four years from their relatively high levels in 1976 and 1977. Given this prospect, the acreage set-aside control variables for farm program No. 2 will most likely be set by the control mechaism at relatively high levels in an attempt to reduce ending year carryovers for feed grains, wheat and cotton to the upper boundary levels specified in the performance measure (Table IV). The situation is made slightly more complicated for program No. 4 by assuring higher 1978 exports then is assumed in running No. 2 and thereby reducing the excess supply in the first year simulated. The control mechanism can determine the acreage set-aside levels for feed grains, wheat and cotton that maintain ending year carryovers of these crops within the desired levels, rather than determining set-aside levels that would reduce the ending year carryovers to the maximum allowable levels.

A grain reserve program, No. 3, is analyzed to demonstrate how control theory can be used to select loan rates and acreage set-aside levels for feed grains, wheat and cotton that cause the CCC to maintain a fixed reserve of grains. A grain reserve of 20 million tons of feed grains and 500 million bushels of wheat is assumed to be established in 1977 by the CCC and the performance measure is modified slightly to encourage the CCC to hold the stocks over the four year period simulated, 1978-1981. The control variables, loan rates and set-aside levels for the three crops, are constrained to the upper and lower boundary constraints for these variables (Tables I and III).

Data Requirements

The POLYSIM model requires a reference baseline of forecasted data. The baseline must include projections of commodity supplies, prices and utilization, as well as aggregate values for receipts and costs. Commodity specialists in ERS develop the five-year projections used in POLYSIM using formal and informal forecasting models tempered with their own experienced judgments. The projections contain explicit assumptions concerning the rates of change in population, per capita incomes, consumer preferences, export demand, technology (including crop yields and livestock gains), and other supply and demand shifters. These projections also assume a specific set of Government farm programs. The particular baseline used for this study is the July 1977 baseline and assumes continuation of the 1973 Agricultural Act through 1982.

For the farm programs analyzed in this study, it was necessary to provide program participation rates, set-aside payment rates, slippage rates, acreage allotments and farm program yields. Values for these policy variables used in this study are presented in Table XIII.

The participation of feed grain, wheat and cotton farmers in a farm program that offers both price and income supports (program No. 1) is expected to be quite high, say 95 percent (Table XIII). On the other hand, a farm program that requires acreage set-asides to be eligible for price and income supports (program No. 2 and No. 4) is likely to have lower participation rates. The participation rates for programs No. 2 and No. 4 are assumed to be: 0.65 for feed grains, 0.80 for wheat and 0.80 for cotton. The relatively low target prices for corn used in programs No. 2 and No. 4 were assumed to reduce participation of corn producers to about 0.50 thus reducing the value for all feed grains.

TABLE XIII

PREDETERMINED VALUES OF PROGRAM PARTICIPATION RATES, SET-ASIDE PAYMENT RATES, SLIPPAGE RATES, ACREAGE ALLOTMENTS, AND FARM PROGRAM YIELDS USED FOR FOUR FARM PROGRAMS

	Farm Programs		
Variable and Crop	No. 1 Price and Income Support	Nos. 2 & 4 Price and Income Support with Acreage Set-Aside	No. 3 Price Support & Acreage Set-Aside with a Grain Reserve Program
Program Participation Rate[1]			
Feed grains	0.95	0.65	0.80
Wheat	0.95	0.80	0.80
Cotton	0.95	0.80	0.80
Set-Aside Payment Rates[2]			
Feed grains		53.43	53.43
Wheat		32.23	32.23
Cotton		78.26	78.26
Slippage Rate[1]			
Feed grains		0.40	0.40
Wheat		0.40	0.40
Cotton		0.40	0.40
Acreage Allotments[1]			
Feed grains	76.0	76.0	
Wheat	56.9	56.9	
Cotton	10.0	10.0	
Farm Program Yields[3]			
Feed grains	2.06	2.06	
Wheat	31.00	31.00	
Cotton	480.00	480.00	

[1]Values for 1978, 1979, 1980 and 1981 are equal to the value reported here.

[2]The set-aside payment rates reported here are for 1978, values for 1979, 1980 and 1981 are obtained by inflating the 1978 value by two percent per year.

[3]The farm program yields reported here are the 1978 values for feed grains and wheat. Feed grain farm program yields are increased by 0.03 ton per acre each year to obtain values for 1979, 1980 and 1981. Wheat farm program yields are increased 0.5 bushels per acre to obtain values for 1979, 1980 and 1981. Cotton farm program yields in 1979, 1980 and 1981 are equal to the value reported in the table for 1978.

Set-aside payment rates can be determined several ways, by sealed bids from individual farmers, by using the total fixed costs of owning the land and machinery to operate it, and by using the total fixed charges for the land. In this study, the set-aside payment rate for each crop is determined as the sum of total general overhead costs, total machinery ownership costs, and 20 percent of the interest and tax charges on the land. Using the average cost of production data provided by the Congressional Agricultural Committee (1977) and the formula above, the per acre set-aside payment rate for feed grains, wheat and cotton is about $52.38, $31.59, and $76.73, respectively in 1977. (The set-aside payment rate for feed grains is a weighted average of the payment rate for corn, sorghum, and barley.) The per acre set-aside payment rates for 1978, reported in Table XIII, are obtained by increasing the 1977 values by two percent.

Slippage is the portion of each acre of set-aside that does not actually result in reducing production, due to farmers declaring their least productive land as set-aside and farmers using variable resources more intensively on the land in cultivation to increase production. Tweeten (1970) reports that prior to 1970 the slippage rate for feed grains was about 0.40 meaning that for each acre of set-aside, production was reduced by only 0.6 acres. Garst and Miller (1975) report the slippage rate for wheat at 0.39 during 1960-1970, and being as high as 0.59 between 1971 and 1974. The slippage rates selected for the acreage set-aside provisions in programs No. 2, No. 3 and No. 4 are 0.40 for feed grains, wheat and cotton (Table XIII).

Acreage allotments or program acreages for feed grains, wheat and cotton are used to calculate deficiency payments. The acreage allotments in the July baseline are at 76.0 million acres for feed grains, 56.9 million acres for wheat and 10.0 million acres for cotton for farm programs No. 1, No. 2, and No. 4. The baseline values for allotments are used in this study to allow comparisons of deficiency payments in the baseline to those calculated for farm programs No. 1, No. 2, and No. 4 (Table XIII). Farm program yields (or administrative yields) of feed grains, wheat and cotton are used in computing deficiency payments for programs No. 1, No. 2, and No. 4 (Table XIII).

Consideration and Results of Applying Optimal Control Techniques to Farm Policy

Each of the farm programs selected for this study are evaluated with respect to the lower range performance measure presented in Table IV. A detailed description of how Box's Complex Procedure solves an optimal control theory problem is presented in Appendix A. In general, the control mechanism systematically searches the surface of the performance measure for its global maximum, by iteratively selecting control paths that increase the value of the performance measure. The solution is at a maximum when a change in any control variable results in reducing the value of the performance measure. The control path associated with the maximum value of the performance measure is the optimum set of values for the control variables.

To insure that the final solution is at the global maximum for the given performance measure, the problem should be run several times. Each time a different set of initial values for the control variables should be used so the procedure is forced to search a different set of control paths. If the procedure returns the same answer each time, the analyst can be fairly certain of having found the global maximum. The four farm programs evaluated for this study were each run three times to determine whether or not a global maximum had been located.

In the Complex Procedure, the performance measure is evaluated each time the control mechanism selects a new control path. To evaluate the performance measure, the new control path is used as input data in the POLYSIM model, and the model is simulated over the four year period, 1978-1981. Simulated values of the output variables in the model are used in the performance measure to obtain a unique real number for evaluating the new control path. The output variables in the performance measure are annual values for realized net farm income, net income for livestock producers, consumer's food expenditures, total government payments, total Commodity Credit Corporation (CCC) interest and storage costs, and the ending year carryovers of feed grains, wheat and cotton (Table IV).

The performance measure includes values for the output variables over the 1978-1981 period so the control mechanism must consider the immediate impacts, as well as the longer run impacts on the output variables when selecting values for the control variables. The control mechanism tries to raise net farm income as high as possible over the four year period while at the same time trying to minimize penalties that accrue when other output variables go outside their acceptable ranges. The control mechanism considers one unit of added income (or penalty) in 1978 equal to one unit of added income (or penalty) in 1979, 1980, or 1981 since the parameter weights are not discounted for time. The optimal solution often results in a trade-off between the added value of net farm income and a change in one or more other output variables; meaning that net farm income could go higher but only by incurring an added penalty due to one or more of the other output variables being outside their respective boundary levels.

For the control mechanism to maximize the performance measure used in this study it must select values for the control variables (loan rates, target prices and acreage set-aside levels for feed grains, wheat and cotton in 1978-1981) with respect to their estimated impacts on the state variables in POLYSIM and the output variables in the performance measure. Both immediate impacts (one year) and longer run impacts (two or more years) are considered by the control mechanism.

In each of the four farm programs selected for the analysis the control mechanism must select optimal values for loan rates of wheat, corn and cotton. To select a value for wheat loan rate in 1978, as well as the longer run impacts in 1979-1981, on the state variables in the model and particularly the impacts on the output variables. The immediate impacts on the following state variables must be considered: the market price of wheat, quantity of domestic and export demands, and wheat cash receipts, as well as, their impacts on the output variables in the performance measure. The longer run impacts that must be considered are impacts on state variables such as: harvested acreage and supply of wheat, feed grains, cotton and soybeans, wheat yields, market prices of wheat, feed grains, cotton and soybeans, the quantity of domestic and export demands for the four model crops and cash receipts for all four model crops, because of their linkages to the output variables.

To select a value for the corn loan rate in 1978 the control mechanism must consider the immediate impacts (1978) on the following state variables: the market price for corn and the other feed grains, export and domestic demands for feed grains, feed grains cash receipts, and livestock feed costs, because of the linkages between these state variables and the output variables in the performance measure. Also, the control mechanism must consider the longer run impacts (1979-1981) on the following state variables: livestock production, prices and cash receipts, harvested acreage for feed grains, wheat, soybeans and cotton, feed grain yields, supplies and prices of the four model crops, domestic and export demands for the model crops, total cash receipts for crops and livestock, and livestock feed costs due to their linkages for farm income, government payments, CCC costs, food costs and ending year carryovers for the four model crops.

The above discussion assumes only the selection of the 1978 loan rates to illustrate the linkages in POLYSIM. Actually, the control mechanism simultaneously selects values for the loan rates of corn, wheat and cotton in 1978, 1979, 1980 and 1981, after considering the impacts of the loan rates on the output variables in the performance measure. The immediate and longer run interrelationships described above for 1978 thus become confused with the immediate and longer run impacts due to selecting loan rates in each of the remaining years.

In addition to selecting values for the loan rates in farm programs No. 2, No. 3, and No. 4, the control mechanism also selects the acreage set-aside levels for feed grains, wheat and cotton in 1978, 1979, 1980 and 1981. The immediate impacts that the control mechanism must consider are the same as those for changing the loan rate, as well as, the impacts on: harvested acreage, production and supply for each of the three crops. The longer run impacts considered by the control mechanism in selecting acreage set-aside levels are the same as those considered when selecting values for the loan rates of the three crops.

In farm program No. 1 the control mechanism selects the target prices as well as loan rates for corn, wheat, and cotton in each of the four years simulated. When selecting target price values, the control mechanism considers the loan rates and market prices for the respective crops, as well as the resulting values of total government payments and realized net farm income in each of the four years simulated. The deficiency payment rate is the smaller of target price minus loan rate or target price minus the market price. Since acreage allotments, farm program yields and program participation rates are fixed for each of the crops, the deficiency payment rate is the only degree of freedom the program has in determining the level of total deficiency payments. The target prices are usually set as high as possible without making total government payments exceed the $3,700 million upper boundary level in the performance measure. The reason for this action is that higher government payments cause realized net income to increase without increasing food costs, changing ending year carryovers for the model crops and without decreasing net incomes for livestock producers.

The control mechanism selects values for all of the control variables simultaneously, after considering the immediate and the longer run impacts of its selections on the output variables in the performance measure. The optimal control paths for the farm policy variables, in the four farm programs selected for evaluation in this study, are presented in the following sections.

Results for Farm Program No. 1

For program No. 1, the control mechanism selects the values of loan rates and target prices for feed grains, wheat and cotton that maximize the performance measure (lower range weights) in Table IV. The optimal values of the control variables, and simulated values for selected state variables in the final solution, are presented in Table XIV. Given farm program No. 1 and the performance measure presented in Table IV, the optimal loan rates for wheat are: $2.01, $2.21, $2.43, and $2.68 in 1978, 1979, 1980 and 1981, respectively (Table XIV). The optimal wheat loan rates are higher than the baseline values for 1980 and 1981, but lower than the baseline in 1978 and 1979. Corn and cotton loan rates selected by the control mechanism are lower than the baseline values in all four years.

The corn loan rates are set just below the calculated corn price in all four years, to prevent the CCC loan actions from raising the price of corn and resulting in higher livestock feed costs and lower net returns for livestock producers. Also, higher corn prices would have caused an increase in the cost of consumer's expenditures for food by reducing livestock production and increasing the prices received for livestock. On the other hand, loan rates for wheat are used to support the average price of wheat in 1980 and 1981 since wheat prices have only minor influence on the consumer's expenditures for food, and raising the price of wheat tends to increase net farm income.

The optimal values of target prices for corn, wheat and cotton are set at their respective lower boundary constraints in 1980 and 1981 (Table XIV). Also, the optimal target prices for cotton in 1978 and 1979

TABLE XIV

OPTIMAL VALUES OF CONTROL VARIABLES AND THE SIMULATED VALUES OF SELECTED STATE VARIABLES FOR FARM PROGRAM NO. 1

Item	Unit	Baseline Values 1978	1979	1980	1981	Simulated Values 1978	1979	1980	1981
CONTROL VARIABLES									
Price Support Levels									
Corn	$/bu.	2.00	2.00	2.00	2.00	1.83	1.89	1.91	1.91
Wheat	ds.	2.35	2.35	2.35	2.35	2.01	2.21	2.43	2.68
Cotton	$/lb.	.51	.51	.51	.51	.42	.44	.48	.50
Income Support Levels									
Corn	$/bu.	2.10	2.21	2.34	2.47	2.26	2.27	2.34[L]	2.47[L]
Wheat	ds.	3.00	3.16	3.34	3.52	3.17[L]	3.19[L]	3.34[L]	3.52[L]
Cotton	$/lb.	.52	.55	.58	.61	.52[L]	.55[L]	.58[L]	.61[L]
Set-Aside									
Feed grains	m. ac.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	ds.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton	ds.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
STATE VARIABLES									
Harvested Acreage									
Feed grains	m. ac.	107.7	107.7	107.4	107.2	107.7	109.3	109.3	108.6
Wheat	ds.	70.7	71.1	71.1	71.1	70.7	71.3	71.7	72.7
Cotton	ds.	11.6	11.4	11.7	11.2	11.6	11.7	11.9	11.4
Yield									
Feed grains	T./ac.	2.06	2.09	2.12	2.15	2.06	2.09	2.12	2.14
Wheat	bu./ac.	31.00	31.50	32.00	32.49	31.00	31.48	32.04	32.74
Cotton	lb./ac.	480.00	480.00	480.00	480.00	480.00	480.00	478.77	477.34
Export Levels									
Feed grains	m. t.	50.4	52.2	53.7	55.4	50.4	52.5	54.6	56.6
Wheat	m. bu.	1025.0	1070.0	1110.0	1160.0	1033.2	1068.2	1090.9	1077.2
Cotton	m. bales	4.5	4.5	4.4	4.4	4.5	4.5	4.5	4.5
Total Utilization									
Feed grains	m. t.	206.2	213.3	223.0	228.6	206.2	211.5	223.2	230.5
Wheat	m. bu.	1925.0	1953.0	1991.0	2049.0	1935.2	1950.8	1966.7	1945.8
Cotton	m. bales	11.6	11.7	11.6	11.8	11.6	11.7	11.7	11.9
Ending Year Carryovers									
Feed grains	m. t.	70.4	82.6	87.5	89.3	70.4	87.7	96.1	98.1
Wheat	m. bu.	1539.0	1827.0	2112.0	2374.0	1528.8	1824.2	2156.8	2590.9
Cotton	m. bales	4.3	4.2	4.5	4.1	4.3	4.4	4.9	4.5

TABLE XIV (CONTINUED)

Item	Unit	Baseline Values 1978	1979	1980	1981	Simulated Values 1978	1979	1980	1981
CCC Inventory and Outstanding Loans									
Feed grains	m. t.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	m. bu.	776.0	1130.0	1497.0	1848.0	28.9	28.9	162.5	693.5
Cotton	m. bales	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commodity Prices									
Corn	$/bu.	2.00	2.00	2.00	2.00	2.00	1.98	1.94	1.93
Wheat	ds.	2.35	2.35	2.35	2.35	2.31	2.37	2.43	2.66
Soybeans	ds.	5.60	5.60	5.70	5.80	4.24	4.68	4.92	4.92
Cotton	$/lb.	.54	.55	.52	.55	.54	.54	.51	.53
Cattle and Calves	ds.	.42	.45	.49	.50	.42	.45	.49	.50
Hogs	ds.	.35	.41	.40	.37	.35	.41	.40	.37
Total Government Payments	B. $	2.019	3.549	4.712	5.850	3.650	3.918	4.862	5.732
Total CCC Storage and Interest Costs	B. $	0.150	0.310	0.452	0.599	0.150	0.012	0.012	0.065
Consumer's Food Expenditures	B. $	188.3	196.8	205.0	214.0	188.3	196.8	204.7	213.4
Livestock Producer's Net Income	B. $	17.312	18.844	19.967	21.289	17.667	18.955	20.005	21.068
Realized Net Farm Income	B. $	18.118	18.949	18.812	19.550	19.186	18.547	18.283	18.621
Performance Measure									111,999.0

[1]Optimal control variables that equal their lower boundary constraints are denoted by superscript "L" and those that equal their upper boundary constraints are denoted by superscript "U".

[2]The performance measure for the optimal solution presented here is the lower range performance measure in Table IV.

are equal to their lower boundary constraints. The optimal target prices for the three crops are set to their lower boundaries in an effort to reduce deficiency payments, since total government payments exceed the upper boundary limit in the performance measure ($3,700 million) in 1979, 1980, and 1981, by $218 million, $1,162 million and $2,032 million, respectively (Table XIV). The control mechanism can select control paths that result in the output variables exceeding their upper boundary levels, if the additional unit increase in the output variable increases net farm income by more than the added penalty decreases the value of the performance measure. In this particular case, the control mechanism could only reduce government payments by increasing the loan rate thus reducing the deficiency payment rates. However, such action would have raised market prices for the crops, resulting in reductions in the quantities demanded for domestic and export use as well as encouraging additional harvested acreage. Taken together these factors would have increased ending year carryovers, thus penalizing the value of the performance measure by more than the high level of government payments.

Harvested acreage for feed grains, wheat and cotton are slightly higher under program No. 1 than the baseline due to the supply response from the slight increase in wheat prices, and the decrease in soybean prices being relatively greater than decreases in either corn or cotton prices (Table XIV). The increase in harvested acreage of wheat and the decrease in the exports of wheat causes ending year stocks of wheat to increase 3.2 percent over the baseline, for the four year period. (Wheat exports are less than the baseline because of higher wheat prices in the last three years.) Ending year carryovers for feed grains and cotton increase 6.8 percent and 5.4 percent, respectively, over the baseline values due to the increases in production being slightly greater than increases in demand for these crops. Production increases over the baseline values due to increases in harvested acreage of feed grains and cotton are a result of prices for these crops being slightly below the baseline values.

Simulated values of realized net farm income for farm program No. 1 are less than those for the reference baseline in 1979, 1980, and 1981 (Table XIV). Over the four year period simulated values for realized net farm income are less than the baseline by about one percent. The optimal control path for farm program No. 1 results in realized net farm income being less than the baseline values even though the performance measure seeks to maximize net farm income. The reason for the lower farm income is that the program also took into consideration the control path's impacts on consumer's food expenditures, the levels of ending year carryovers for the crops, total CCC storage and interest costs and the levels of total government payments.

Results for Farm Program No. 2

Farm program No. 2 is a price and income support program with a voluntary acreage set-aside provision to enable the government to reduce harvested acreages for feed grains, wheat and cotton. The control mechanism selects the optimal loan rates and acreage set-aside levels for feed grains, wheat and cotton in 1978, 1979, 1980 and 1981. The optimal solution of the performance measure, in Table IV (low range parameter weights), for farm program No. 2 is presented in Table XV. The value of the

TABLE XV

OPTIMAL VALUES OF CONTROL VARIABLES AND THE SIMULATED VALUES OF SELECTED STATE VARIABLES FOR FARM PROGRAM NO. 2

Item	Unit	Baseline Values 1978	1979	1980	1981	Simulated Values 1978	1979	1980	1981
CONTROL VARIABLES									
Price Support Levels									
Corn	$/bu.	2.00	2.00	2.00	2.00	1.80	1.82	1.82	1.84
Wheat	ds.	2.35	2.35	2.35	2.35	2.18	2.21	2.39	2.39
Cotton	$/lb.	.51	.51	.51	.51	.47	.49	.51	.53
Income Support Levels									
Corn	$/bu.	2.10	2.21	2.34	2.47	2.10	2.21	2.34	2.47
Wheat	ds.	3.00	3.16	3.34	3.52	3.00	3.16	3.34	3.52
Cotton	$/lb.	.52	.55	.58	.61	.52	.55	.58	.61
Set-Aside									
Feed grains	m. ac.	0.0	0.0	0.0	0.0	9.9	19.9	19.6	18.1
Wheat	ds.	0.0	0.0	0.0	0.0	24.7^{U}	24.8^{U}	24.8^{U}	24.6
Cotton	ds.	0.0	0.0	0.0	0.0	3.2^{U}	3.3^{U}	3.0	2.5
STATE VARIABLES									
Harvested Acreage									
Feed grains	m. ac.	107.7	107.7	107.4	107.2	101.8	97.3	97.8	97.9
Wheat	ds.	70.7	71.1	71.1	71.1	55.9	56.7	57.6	58.2
Cotton	ds.	11.6	11.4	11.7	11.2	9.7	10.0	10.8	10.5
Yield									
Feed grains	T./ac.	2.06	2.09	2.12	2.15	2.06	2.10	2.15	2.19
Wheat	bu./ac.	31.00	31.50	32.00	32.49	31.00	31.61	32.42	33.15
Cotton	lb./ac.	480.00	480.00	480.00	480.00	480.00	488.69	497.08	500.56
Export Levels									
Feed grains	m. t.	50.4	52.2	53.7	55.4	49.3	49.1	49.2	50.1
Wheat	m. bu.	1025.0	1070.0	1110.0	1160.0	991.0	933.1	910.9	926.6
Cotton	m. bales	4.5	4.5	4.4	4.4	4.2	4.0	3.9	3.9
Total Utilization									
Feed grains	m. t.	206.2	213.3	223.0	228.6	204.6	204.6	209.8	214.8
Wheat	m. bu.	1925.0	1953.0	1991.0	2049.0	1884.0	1786.9	1747.5	1761.9
Cotton	m. bales	11.6	11.7	11.6	11.8	11.2	11.0	10.8	11.1
Ending Year Carryovers									
Feed grains	m. t.	70.4	82.6	87.5	89.3	59.9	59.9	60.3	60.1
Wheat	m. bu.	1539.0	1827.0	2112.0	2374.0	1119.9	1125.4	1247.5	1417.3
Cotton	m. bales	4.3	4.2	4.5	4.1	2.7	2.1	2.6	2.6

TABLE XV (CONTINUED)

Item	Unit	Baseline Values 1978	1979	1980	1981	Simulated Values 1978	1979	1980	1981
CCC Inventory and Outstanding Loans									
Feed grains	m. t.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	m. bu.	776.0	1130.0	1497.0	1848.0	0.8	0.0	0.0	0.0
Cotton	m. bales	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commodity Prices									
Corn	$/bu.	2.00	2.00	2.00	2.00	2.09	2.21	2.26	2.27
Wheat	ds.	2.35	2.35	2.35	2.35	2.51	2.90	3.00	3.03
Soybeans	ds.	5.60	5.60	5.70	5.80	4.32	4.83	6.00	6.28
Cotton	$/lb.	.54	.55	.52	.55	.61	.65	.61	.63
Cattle and Calves	ds.	.42	.45	.49	.50	.43	.46	.51	.52
Hogs	ds.	.35	.41	.40	.37	.35	.42	.43	.40
Total Government Payments	B. $	2.019	3.549	4.712	5.850	3.180	3.460	3.680	4.266
Total CCC Storage and Interest Costs	B. $	0.150	0.310	0.452	0.599	0.150	0.017	0.0	0.0
Consumer's Food Expenditures	B. $	188.3	196.8	205.0	214.0	188.3	197.7	207.1	216.5
Livestock Producer's Net Income	B. $	17.312	18.844	19.967	21.289	17.345	18.848	20.668	22.420
Realized Net Farm Income	B. $	18.118	18.949	18.812	19.550	18.874	18.913	19.926	21.589
Performance Measure									127,968.0

[1]Optimal control variables that equal their lower boundary constraints are denoted by superscript "L" and those that equal their upper boundary constraints are denoted by superscript "U".

[2]The performance measure for the optimal solution presented here is the lower range performance measure in Table IV.

performance measure for the optimal solution is 127,968. The optimal loan rates for corn, wheat and cotton are less than the average prices of the respective crops. So the loan rates for the three crops do not influence the average prices received by farmers and could be set to their respective lower boundary constraints without appreciably changing the solution.

Target prices for corn, wheat and cotton are predetermined, at their respective levels established in the 1977 Agricultural Act, for this farm program. By fixing the target prices, allotted acreage and farm program yields the deficiency payment is completely determined once loan rates and market prices are known. When the market price is greater than the loan rate, as in Table XV, the deficiency payment rate is the target price minus the market price. As the market price is brought closer to the target price, the deficiency payment approaches zero. This relationship partially explains why acreage set-aside is used to raise the average market price for corn, wheat and cotton to relatively high levels (Table XV).

Optimal acreage set-aside levels for wheat are equal to the upper boundary constraints for wheat (about 24.8 million acres) in all four years simulated (Table XV). The optimal acreage set-aside levels for cotton equal the upper boundary constraint (about 3.2 million acres) in the first two years simulated, 1978 and 1979. While the acreage set-aside levels for feed grains (about 20 million acres) are about one half as large as their upper limits of 37.7 million acres. High levels of set-aside for wheat are used in the solution because they reduce wheat production causing the average market price of wheat to increase which reduces the deficiency payments for wheat. Another reason for the high levels of acreage set-aside for wheat is to decrease the ending year carryovers of wheat to the upper limit specified in the performance measure (1200 million bushels).

Acreage set-aside levels for feed grains are sufficiently high each year to reduce the ending year carryovers of feed grains to about 60 million tons, the upper limit in the performance measure for this output variable. To achieve this goal the optimal quantity of feed grain acreage diversion changes from year to year; it is 10 million acres in 1978, 20 million in 1979 and 1980, and 18 million in 1981 (Table XV). Higher levels of feed grain set-aside are not used since they do not improve the value of the performance measure after once reducing carryovers to 60 million tons. Also, higher levels of feed grain set-aside would reduce the value of the performance measure by increasing corn prices which result in decreases in net incomes for livestock producers and in the following year result in increases in consumer expenditures for food. Acreage set-aside levels for cotton cause the ending year carryovers of cotton to be reduced to the acceptable range of 2.0 to 4.0 million bales, in the performance measure. The resulting prices of cotton are greater than the target price for cotton thus reducing the deficiency payments for cotton to zero (Table XV).

Government payments for farm program No. 2 are less than the $3,700 million limit imposed on the performance measure, in all but the last year simulated when government payments are $4,266 million (Table XV). Total government payments could not be decreased to the $3,700 million limit in the last year simulated because higher wheat set-aside is not possible, higher cotton set-aside only increases cotton payments for set-aside since no deficiency payments are paid for cotton and higher levels of acreage set-aside for feed grains result in higher corn prices which cause an immediate reduction of net income to livestock producers and thus reduce the value of the performance measure.

In the aggreagate, farm program No. 2 tends to increase both net income for livestock producers and total realized net farm income over the values in the baseline (Table XV). Realized net farm income is increased 10.4 percent in 1982 over its baseline value and the average increase over the four year period is about five percent. The optimal levels of acreage set-aside for feed grains, wheat and cotton in farm program No. 2 result in moderate increases in consumer's food expenditures over the baseline. Over the four year period, total consumer's food costs are estimated to increase about 0.7 percent over the baseline values.

Results for Farm Program No. 3

Farm program No. 3 is a price support and acreage set-aside program with a grain reserve provision. The control variables for the farm program are loan rates and acreage set-aside levels for feed grains, wheat and cotton in 1978, 1979, 1980 and 1981. The optimal values for the control variables in farm program No. 3 are presented in Table XVI. Farm program No. 3 includes a grain reserve provision that encourages the CCC to hold 20 million tons of feed grains and 500 million bushels of wheat. The CCC reserve of feed grains and wheat is assumed to be acquired in 1977. The objective is to determine loan rates and acreage set-aside levels that maximize the performance measure (lower range of weights) in Table IV, subject to the added constraint of maintaining the initial level of grain reserves from 1978 through 1981. The CCC release rule used for farm program No. 3 is the following: release CCC held reserves if the

TABLE XVI

OPTIMAL VALUES OF CONTROL VARIABLES AND THE SIMULATED VALUES
OF SELECTED STATE VARIABLES FOR FARM PROGRAM NO. 3

Item	Unit	Baseline Values 1978	1979	1980	1981	Simulated Values 1978	1979	1980	1981
CONTROL VARIABLES									
Price Support Levels									
Corn	$/bu.	2.00	2.00	2.00	2.00	1.80	1.94	2.10	2.18
Wheat	ds.	2.35	2.35	2.35	2.35	2.23	2.26	2.44	2.46
Cotton	$/lb.	.51	.51	.51	.51	.38	.38	.42	.46
Income Support Levels									
Corn	$/bu.	2.10	2.21	2.34	2.47	0.0	0.0	0.0	0.0
Wheat	ds.	3.00	3.16	3.34	3.52	0.0	0.0	0.0	0.0
Cotton	$/lb.	.52	.55	.58	.61	0.0	0.0	0.0	0.0
Set-Aside									
Feed grains	m. ac.	0.0	0.0	0.0	0.0	11.8[U]	20.9[U]	27.8[U]	31.9[U]
Wheat	ds.	0.0	0.0	0.0	0.0	24.6[U]	24.8[U]	24.8[U]	24.8[U]
Cotton	ds.	0.0	0.0	0.0	0.0	3.2[U]	3.3[U]	3.1[U]	3.2[U]
STATE VARIABLES									
Harvested Acreage									
Feed grains	m. ac.	107.7	107.7	107.4	107.2	100.6	96.3	92.9	90.3
Wheat	ds.	70.7	71.1	71.1	71.1	55.9	57.7	58.5	58.6
Cotton	ds.	11.6	11.4	11.7	11.2	9.7	9.9	10.7	10.0
Yield									
Feed grains	T./ac.	2.06	2.09	2.12	2.15	2.06	2.10	2.16	2.22
Wheat	bu./ac.	31.00	31.50	32.00	32.49	31.00	31.89	32.71	33.37
Cotton	lb./ac.	480.00	480.00	480.00	480.00	480.00	488.66	497.21	501.24
Export Levels									
Feed grains	m. t.	50.4	52.2	53.7	55.4	49.1	46.9	45.9	46.0
Wheat	m. bu.	1025.0	1070.0	1110.0	1160.0	900.4	854.6	857.8	894.0
Cotton	m. bales	4.5	4.5	4.4	4.4	4.2	4.0	3.9	3.8
Total Utilization									
Feed grains	m. t.	206.2	213.3	223.0	228.6	204.2	201.0	201.2	204.3
Wheat	m. bu.	1925.0	1953.0	1991.0	2049.0	1770.6	1688.6	1681.6	1723.5
Cotton	m. bales	11.6	11.7	11.6	11.8	11.2	11.0	10.8	10.9
Ending Year Carryovers									
Feed grains	m. t.	70.4	82.6	87.5	89.3	57.8	59.5	59.7	55.8
Wheat	m. bu.	1539.0	1827.0	2112.0	2374.0	1235.2	1385.9	1620.0	1852.6
Cotton	m. bales	4.3	4.2	4.5	4.1	2.7	2.0	2.5	2.1

TABLE XVI (CONTINUED)

Item	Unit	Baseline Values 1978	1979	1980	1981	Simulated Values 1978	1979	1980	1981
CCC Inventory and Outstanding Loans									
Feed grains	m. t.	0.0	0.0	0.0	0.0	20.0	20.0	20.0	20.0
Wheat	m. bu.	776.0	1130.0	1497.0	1848.0	500.0	500.0	500.0	500.0
Cotton	m. bales	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commodity Prices									
Corn	$/bu.	2.00	2.00	2.00	2.00	2.11	2.37	2.45	2.49
Wheat	ds.	2.35	2.35	2.35	2.35	2.92	3.11	3.11	3.09
Soybeans	ds.	5.60	5.60	5.70	5.80	4.32	4.88	6.16	6.49
Cotton	$/lb.	.54	.55	.52	.55	.60	.65	.61	.65
Cattle and Calves	ds.	.42	.45	.49	.50	.42	.46	.52	.53
Hogs	ds.	.35	.41	.40	.37	.35	.42	.45	.41
Total Government Payments	B. $	2.019	3.549	4.712	5.850	2.544	3.144	3.359	3.696
Total CCC Storage and Interest Costs	B. $	0.150	0.310	0.452	0.599	0.150	0.253	0.253	0.253
Consumer's Food Expenditures	B. $	188.3	196.8	205.0	214.0	188.3	197.9	208.7	218.1
Livestock Producer's Net Income	B. $	17.312	18.844	19.967	21.289	17.169	18.425	21.549	23.232
Realized Net Farm Income	B. $	18.118	18.949	18.812	19.550	18.641	18.995	21.634	22.911
Performance Measure									123,162.0

[1] Optimal control variables that equal their lower boundary constraints are denoted by superscript "L" and those that equal their upper boundary constraints are denoted by superscript "U".

[2] The performance measure for the optimal solution presented here is the lower range performance measure in Table IV.

average market price exceeds the loan rate by 50 percent and release only the amount of stocks needed to lower the average market price to 150 percent of the loan rate.

Loan rates are not used by the control mechanism to support the market price in this particular farm program since the support action results in the CCC acquiring control of additional stocks. So acreage set-aside is the predominate control variable for farm program No. 3. The optimal acreage set-aside levels for wheat and cotton are equal to the crop's respective upper boundary constraints in each of the four years simulated (Table XVI). Optimal acreage set-aside levels for feed grains range from 12 million acres to 32 million acres over the period simulated (Table XVI). So the feed grain acreage diversion levels are less than the boundary constraints (about 37 million acres); but are larger than the set-aside levels for feed grains in farm program No. 2 (Tables XV and XVI).

The high levels of acreage set-aside for feed grains, wheat and cotton cause the average market prices for these crops to be greater than the respective market prices in the baseline for each of the years simulated (Table XVI). The corn loan rate is increased from year to year but is never greater than the market price and it is never less than the market price by more than 50 percent. So the CCC release and acquisition rule for corn is never activated. A similar situation exists for wheat.

The total government payments for miscellaneous farm programs and acreage set-aside is less than the $3,700 million upper limit imposed on the performance measure, in each year simulated (Table XVI). The upper limit is almost passed in 1981 with total government payments of

$3,696 million. Additional acreage set-aside of feed grains is possible in 1981; however, higher levels of set-aside would increase total government payments over the upper limit and penalize the performance measure. Realized net farm income for farm program No. 3 is higher than the baseline values in each year simulated, and over the four years the simulated net farm income is nine percent greater than the baseline.

Results for Farm Program No. 4

The optimal levels of acreage set-aside and loan rates for farm program No. 4 (program No. 2 with increased export demands in 1978) are presented in Table XVII. The quantity of exports in 1978 for feed grains, wheat and cotton is predetermined at a relatively high level, to reduce the ending year carrovers of these crops (Table XVII). The predetermined value of exports equals the baseline export value in 1978, plus the percentage increase in exports between 1971 and 1972 (86 percent for feed grains, 58 percent for wheat and 57 percent for cotton). Target prices for farm program No. 4 are fixed at the baseline levels. The value of the performance measure for the optimal solution of program No. 4 is 131,946.0 as compared to 127,968.0 for farm program No. 2.

The high level of exports in 1978 reduce the ending year carryovers of feed grains, wheat and cotton, thus reducing the need for acreage set-aside in 1978 for these crops (Table XVII). Optimal acreage set-aside levels for feed grains and cotton are less than 1.0 million acres in 1978. The resulting ending year carryovers for feed grains and cotton are approximately equal to the lower levels of these state variables in the performance measure, 30 million tons and 2 million bales, respectively (Table XVII).

TABLE XVII

OPTIMAL VALUES OF CONTROL VARIABLES AND THE SIMULATED VALUES OF SELECTED STATE VARIABLES FOR FARM PROGRAM NO. 4

Item	Unit	Baseline Values				Simulated Values			
		1978	1979	1980	1981	1978	1979	1980	1981
CONTROL VARIABLES									
Price Support Levels									
Corn	$/bu.	2.00	2.00	2.00	2.00	2.10^{U}	2.19	2.20	2.20
Wheat	ds.	2.35	2.35	2.35	2.35	3.00^{U}	3.14	3.30	3.48
Cotton	$/lb.	.51	.51	.51	.51	.46	.51	.55	.58
Income Support Levels									
Corn	$/bu.	2.10	2.21	2.34	2.47	2.10	2.21	2.34	2.47
Wheat	ds.	3.00	3.16	3.34	3.52	3.00	3.16	3.34	3.52
Cotton	$/lb.	.52	.55	.58	.61	.52	.55	.58	.61
Set-Aside									
Feed grains	m. ac.	0.0	0.0	0.0	0.0	0.6	21.1	22.0$_{U}$	16.7$_{U}$
Wheat	ds.	0.0	0.0	0.0	0.0	24.3	24.4$_{U}$	24.8$_{U}$	24.7^{U}
Cotton	ds.	0.0	0.0	0.0	0.0	0.8	3.3^{U}	3.1^{U}	2.8
STATE VARIABLES									
Harvested Acreage									
Feed grains	m. ac.	107.7	107.7	107.4	107.2	106.8	99.9	97.2	98.0
Wheat	ds.	70.7	71.1	71.1	71.1	57.9	58.7	59.3	60.1
Cotton	ds.	11.6	11.4	11.7	11.2	11.0	12.1	11.0	10.1
Yield									
Feed grains	T./ac.	2.06	2.09	2.12	2.15	2.07	2.21	2.21	2.22
Wheat	bu./ac.	31.00	31.50	32.00	32.49	31.52	32.50	33.14	33.84
Cotton	lb./ac.	480.00	480.00	480.00	480.00	480.00	551.09	515.42	505.57
Export Levels									
Feed grains	m. t.	50.4	52.2	53.7	55.4	93.8	64.0	54.2	52.1
Wheat	m. bu.	1025.0	1070.0	1110.0	1160.0	1617.3	1069.2	884.9	819.1
Cotton	m. bales	4.5	4.5	4.4	4.4	7.1	5.4	4.6	4.3
Total Utilization									
Feed grains	m. t.	206.2	213.3	223.0	228.6	243.1	194.2	214.8	218.5
Wheat	m. bu.	1925.0	1953.0	1991.0	2049.0	2477.4	1890.9	1689.0	1616.5
Cotton	m. bales	11.6	11.7	11.6	11.8	13.4	12.1	11.4	11.4
Ending Year Carryovers									
Feed grains	m. t.	70.4	82.6	87.5	89.3	32.7	59.8	60.0	59.2
Wheat	m. bu.	1539.0	1827.0	2112.0	2374.0	619.4	637.8	915.4	1333.6
Cotton	m. bales	4.3	4.2	4.5	4.1	1.9	3.8	4.4	3.9

TABLE XVII (CONTINUED)

Item	Unit	Baseline Values 1978	1979	1980	1981	Simulated Values 1978	1979	1980	1981
CCC Inventory and Outstanding Loans									
Feed grains	m. t.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	m. bu.	776.0	1130.0	1497.0	1848.0	122.2	122.2	129.8	314.7
Cotton	m. bales	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
Commodity Prices									
Corn	$/bu.	2.00	2.00	2.00	2.00	3.12	2.28	2.23	2.25
Wheat	ds.	2.35	2.35	2.35	2.35	3.45	3.22	3.30	3.43
Soybeans	ds.	5.60	5.60	5.70	5.80	4.46	6.02	6.50	6.01
Cotton	$/lb.	.54	.55	.52	.55	1.07	.55	.54	.59
Cattle and Calves	ds.	.42	.45	.49	.50	.42	.54	.49	.52
Hogs	ds.	.35	.41	.40	.37	.35	.56	.40	.40
Total Government Payments	B. $	2.019	3.549	4.712	5.850	1.755	3.137	3.600	3.707
Total CCC Storage and Interest Costs	B. $	0.150	0.310	0.452	0.599	0.150	0.049	0.049	0.054
Consumer's Food Expenditures	B. $	188.3	196.8	205.0	214.0	188.3	206.6	205.4	216.7
Livestock Producer's Net Income	B. $	17.312	18.844	19.967	21.289	13.501	27.449	19.564	22.728
Realized Net Farm Income	B. $	18.118	18.949	18.812	19.550	18.800	32.055	20.272	21.861
Performance Measure									131,946.0

[1]Optimal control variables that equal their lower boundary constraints are denoted by superscript "L" and those that equal their upper boundary constraints are denoted by superscript "U".

[2]The performance measure for the optimal solution presented here is the lower range performance measure in Table IV.

Set-aside for wheat in 1978 is 24.3 million acres, just slightly less than the maximum number of acres (24.7 million) that can be set-aside in 1978 (Table XVII). High levels of wheat set-aside are used in 1978, in an effort to reduce the large carryin of wheat from 1977 (1,270 million bushels) in anticipation of the large carryovers in 1981. The acreage set-aside levels of wheat in 1979 and 1980 (24.4 and 24.8 million acres, respectively) are about equal to the upper boundary constraint for these control variables (Table XVII). An explantion of the high set-aside levels for wheat is that they are set high in 1979 and 1980 in an effort to hold carryovers for 1981 as close as possible to the 1,200 million bushel limit in the performance measure.

Acreage set-aside levels for feed grains in 1979 and 1980 are slightly higher for farm program No. 4 than for program No. 2; but acreage diversions are well below the maximums established by the upper boundary constraints in Table III. The reason for the increase in acreage set-aside is that to maintain ending year carryover of feed grains at about 60 million tons, additional acreage set-aside is needed to remove the effect of increases in feed grain harvested acreage and yields, that result from increases in feed grain price (corn).

Optimal set-aside levels for cotton are equal to their upper boundary constraints in 1979 and 1980 (3.3 and 3.1 million acres, respectively) in an effort to reduce the carryover in 1980 to 4 million bales, the upper limit in the performance measure (Table XVII). The complexities of farm program No. 4 demonstrate the dynamic properties of control theory, i.e., the optimal values selected for the acreage set-aside control variables in 1979 and 1980 are selected due not only to their immediate but also their longer run impacts on the performance measure.

The average market prices received for the model crops are considerably higher under farm program No. 4 than their respective values in the baseline and in program No. 2 (Table XVII). The higher prices are due in part to the increase in export demands for feed grains, wheat and cotton and to the high levels of acreage set-asides selected by the control mechanism. Also, loan rates for wheat and cotton are used to support the average market prices in 1980 and 1981. The selection of the loan rates for cotton are interesting in that the 1978 and 1979 values are the lowest possible values that permit a loan rate of $0.55 per pound in 1980 (Table XVII). A constraint on the annual increase in loan rates prohibits increases of more than ten percent a year and this is the rate of increase between 1978 and 1979 and between 1979 and 1980.

Prices of beef cattle and hogs increase six percent and eleven percent, respectively, over the baseline values for 1978-1981 for farm program No. 4 (Table XVII). The increases in livestock prices are due to lower livestock supplies in response to increases in feed costs. The higher livestock prices are passed on to the consumer in the form of higher food costs (Table XVII). Over the four year period, total expenditures for food increases 1.6 percent over the baseline values and for the last three years, food expenditures increase about three percent. The impacts on food costs due to increases in the feed costs in 1978 primarily accrue in 1979 and 1980.

Realized net farm income for farm program No. 4 increases about 23 percent over the baseline between 1978 and 1981 (Table XVII). The primary increase in net farm income is in 1979 when net farm income increases from $18.9 billion to $32.1 billion. This 70 percent increase is due primarily to the livestock sectors response to the higher feed costs in 1978.

Sensitivity of the Optimal Solution to Changes In the Performance Measure

The final solutions for farm program Nos. 1, 2, 3 and 4 are optimal for the lower range performance measure in Table IV. A change in the upper and lower boundary levels used in the performance weights associated with the boundary levels may cause changes in the optimal solution for the farm programs. A sensitivity analysis could be done for each farm program to determine the sensitivity of the optimal solution to changes in parameter weights and boundary levels for the critical variables in the performance measure. To demonstrate the type of information that a sensitivity analysis can provide, farm program No. 1 is solved a second time using the higher range of weights for the performance measure in Table IV.

The higher range performance measure has higher parameter weights (in absolute terms) for the boundary levels of consumer's food expenditures, total government payments and total CCC storage and interest costs (Table IV). For example, the upper boundary parameter weight for total government payments is changed from -1.5 to -4.0, implying that for each unit of expense over the upper boundary level ($3,700 million) the disutility is $4 to 2.66 times more disutility than when a weight of -1.5 is used. The increased penalty (disutility) associated with government payments exceeding the upper boundary level causes the control mechanism to select values for the control variables that tend to hold government payments closer to the acceptable range. The optimal solutions for farm program No. 1, using both performance measures in Table IV are presented in Table XVIII.

TABLE XVIII

OPTIMAL VALUES FOR CONTROL VARIABLES AND THE SIMULATED VALUES OF SELECTED STATE VARIABLES FOR FARM PROGRAM NO. 1, USING BOTH THE LOWER RANGE PARAMETER WEIGHTS AND THE HIGHER RANGE PARAMETER WEIGHTS IN THE PERFORMANCE MEASURE

Item	Unit	Simulated Values Using Lower Range				Simulated Values Using Higher Range			
		1978	1979	1980	1981	1978	1979	1980	1981
CONTROL VARIABLES									
Price Support Levels									
Corn	$/bu.	1.83	1.89	1.91	1.91	1.75[L]	1.78	1.90	2.03
Wheat	ds.	2.01	2.21	2.43	2.68	2.39	2.62	2.89	3.17
Cotton	$/lb.	.42	.44	.48	.50	.51	.54	.58	.61
Income Support Levels									
Corn	$/bu.	2.26	2.27	2.34[L]	2.47[L]	2.10[L]	2.21[L]	2.34[L]	2.47[L]
Wheat	ds.	3.17	3.19	3.34[L]	3.52[L]	3.47	3.47	3.47	3.52[L]
Cotton	$/lb.	.52[L]	.55[L]	.58[L]	.61[L]	.56	.57	.58[L]	.61[L]
Set-Aside									
Feed grains	m. ac.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheat	ds.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton	ds.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
STATE VARIABLES									
Harvested Acreage									
Feed grains	m. ac.	107.7	109.3	109.3	108.6	107.5	108.7	108.3	107.7
Wheat	ds.	70.7	71.3	71.7	72.7	71.2	72.5	73.6	74.4
Cotton	ds.	11.6	11.7	11.9	11.4	11.6	11.7	12.2	12.1
Yield									
Feed grains	T./ac.	2.06	2.09	2.12	2.14	2.06	2.09	2.12	2.15
Wheat	bu./ac.	31.00	31.48	32.04	32.74	31.10	31.70	32.50	33.30
Cotton	lb./ac.	480.00	480.00	478.77	477.34	480.00	480.03	483.72	494.27
Export Levels									
Feed grains	m. t.	50.4	52.5	54.6	56.6	50.4	52.4	54.2	55.2
Wheat	m. bu.	1033.2	1068.2	1090.9	1077.2	972.6	991.7	962.4	914.4
Cotton	m. bales	4.5	4.5	4.5	4.5	4.5	4.5	4.2	4.1
Total Utilization									
Feed grains	m. t.	206.2	211.5	223.2	230.5	206.1	211.2	222.6	227.9
Wheat	m. bu.	1935.2	1950.8	1966.7	1945.8	1859.2	1853.6	1805.2	1842.3
Cotton	m. bales	11.6	11.7	11.7	11.9	11.6	11.7	11.3	11.4
Ending Year Carryovers									
Feed grains	m. t.	70.4	87.7	96.1	98.1	70.0	86.5	96.6	97.6
Wheat	m. bu.	1528.8	1824.2	2156.8	2590.9	1625.6	2073.3	2660.0	3396.2
Cotton	m. bales	4.3	4.4	4.9	4.5	4.3	4.4	5.5	6.9

TABLE XVIII (CONTINUED)

Item	Unit	Simulated Values Using Lower Range 1978	1979	1980	1981	Simulated Values Using Higher Range 1978	1979	1980	1981
CCC Inventory and Outstanding Loans									
Feed grains	m. t.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3
Wheat	m. bu.	28.9	28.9	162.5	693.5	375.0	554.7	1201.1	2017.6
Cotton	m. bales	0.0	0.0	0.0	0.0	0.0	0.0	2.7	4.0
Commodity Prices									
Corn	$/bu.	2.00	1.98	1.94	1.93	2.00	1.99	1.96	2.03
Wheat	ds.	2.31	2.37	2.43	2.66	2.59	2.62	2.86	3.15
Soybeans	ds.	4.24	4.68	4.92	4.92	4.24	4.71	4.92	4.92
Cotton	$/lb.	.54	.54	.51	.53	.54	.54	.57	.61
Cattle and Calves	ds.	.42	.45	.49	.50	.42	.45	.49	.50
Hogs	ds.	.35	.41	.40	.37	.35	.41	.40	.37
Total Government Payments	B. $	3.650	3.918	4.862	5.732	2.969	3.724	3.824	3.834
Total CCC Storage and Interest Costs	B. $	0.150	0.012	0.012	0.065	0.150	0.150	0.277	0.480
Consumer's Food Expenditures	B. $	188.3	196.8	204.7	213.4	188.3	196.8	204.8	213.6
Livestock Producer's Net Income	B. $	17.667	18.955	20.005	21.068	17.609	18.915	19.983	20.858
Realized Net Farm Income	B. $	19.186	18.547	18.283	18.621	18.862	18.916	18.425	18.213
Performance Measure					111,999.0				93715.0

[1]Optimal control variables that equal their lower boundary constraints are denoted by superscript "L" and those that equal their upper boundary constraints are denoted by superscript "U"

As hypothesized above, total government payments for farm program No. 1 are less for the optimal solution using the high range of weights than for the optimal solution using the low range of weights (Table XVIII). The reduction in total food costs due to shifting from the low set of weights to the high set is about $0.3 billion over the four year period, given farm program No. 1. Total CCC costs are higher for the high range of weights, however the costs do not exceed the $600 million upper limit established in the performance measure.

The optimal levels of the control variables for farm program No. 1 are slightly different for the two performance measures. Loan rates for wheat with the higher weights on the three output measures in the performance measure are $2.39, $2.62, $2.89 and $3.17 for 1978 through 1981, with $2.01, $2.21, $2.43 and $2.68 for 1978 through 1981, with the lower set of weights (Table XVIII). The higher loan rates for wheat are used to support the average market price of wheat to higher levels and thus result in larger accumulation of stocks by the CCC (2,017.6 million bushels in 1981 versus 693.5 million bushels in 1981). An explanation for the control mechanism using the wheat loan rate to support the price of wheat, is that the higher penalty on total government expenditures makes the use of large deficiency payments to raise net farm income less desirable. Since higher market prices reduce the deficiency payment rate for a given target price and increase net farm income the control mechanism uses the loan rate to increase the price. The same explanation can be used to explain the high support prices of cotton in 1980 and 1981 that cause the CCC to acquire stocks of cotton (2.7 million bales in 1980 and 1.3 million bales in 1981).

The higher ranges of parameter weights on government payments leads the control mechanism to select values for the target prices that are closer to the market prices for the respective crops than the target prices for the lower range of weights (Table XVIII). As mentioned before, the reason for this action is to reduce the deficiency payment rate. The target prices of wheat for farm program No. 1 are \$3.17, \$3.19, \$3.34, and \$3.52 in 1978, 1979, 1980 and 1981, respectively when the low range of weights are used for the performance measure and the target prices are \$3.47, \$3.47, \$3.47 and \$3.52 in 1978, 1979, 1980 and 1981 when the high range of weights are used (Table XVIII). However, the deficiency payment rates for wheat are less for the target prices associated with the higher range of weights, than for the target prices associated with the lower range of weights.

The two solutions for farm program No. 1 in Table XVIII indicate that changes in the parameter weights in the performance measure can result in changes in the optimal values of the control variables, and the state variables. The sensitivity of the optimal values for the control variables, to changes in the parameter weights for the performance measure is a critical factor in using control theory and requires attention. In application, analysts can obtain estimates of the parameter weights directly from the decision makers to reduce the uncertainty surrounding these parameters. And as Rausser and Freebairn (1974) indicate a range of parameter weights may be used in the analysis rather than using single valued estimates of the parameter weights.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Problem Statement

The commercial farm problem in the U. S. was brought to the attention of decision makers by dissatisfied farmers in the early 1920's, following drastic decreases in farm prices after World War I. The symptoms of the commercial farm problem at that time included: chronic overproduction, depressed prices for agricultural outputs and low rates of return for the factors of production. The same symptoms of the farm problem have persisted over most of the last half century.

Several factors have been identified as contributing to the commercial farm program; these are: 1) rapid technological advancements that increase agricultural productivity faster than the growth in demand for food, 2) the competitive nature of agriculture that essentially requires farmers to adopt new technology to remain in the industry, 3) resource immobility or fixity in agriculture, 4) the price inelasticity of short-run supply of agricultural products and the inelastic demand for food with respect to both price and income (Heady, 1962; Tweeten, 1970; Brandow, 1977).

Farm programs have been used to deal with the symptoms of the farm problems in the past and as long as the farm problem exists, there will be a need for economists to analyze the alternative farm programs and to make recommendations to the decision makers involved in developing farm policies. The primary interest groups involved in developing farm programs have been farmers, consumers and taxpayers. Farmers want high incomes with minimal governmental interference, while consumers want a stable supply of food at low prices, and taxpayers want low treasury costs. Since these interests are conflicting and since the political powers of each group have changed over time, farm programs have been developed in a piecemeal fashion (Tweeten, 1970). With the added interest in government costs and the growth in political powers of consumer groups, farm policy analysts in the future must be prepared to incorporate the interests of all three groups into their analyses more precisely than they have in the past.

Objectives

The general objectives of the thesis were to demonstrate the use of optimal control techniques for analyzing farm policy. The specific objectives were to: 1) demonstrate the benefits from using optimal control techniques in conjunction with a simulation model; 2) develop a conceptual performance measure for evaluating farm policies, given the goals of the three interest groups involved in policy decisions; and 3) indicate the type of results one can obtain from using control theory techniques to select values for farm policy variables, such as, loan rates, target prices, and acreage set-aside levels.

The objectives of the thesis were accomplished by adapting a control theory procedure to a national agricultural policy simulation model. The model selected was the National Agricultural Policy Simulator (POLYSIM), a computerized model developed by Daryll E. Ray and the author at Oklahoma State University (Ray and Richardson, 1978).

Methodology

Control theory is a mathematical technique that can be used to determine the levels of control variables that cause a particular system to satisfy a given set of boundary constraints and at the same time cause a given performance measure to be at a maximum (or minimum) (Jacobs, 1975; Kirk, 1970; Sage, 1968). In application the control mechanism selects values for the control variables, determines their impacts on the system's output variables and evaluates the performance measure based on the values of the relevant output variables. This process is usually repeated in an iterative fashion until any change in the control variables results in a reduction in the value of the performance measure.

The system being controlled in this study is the agricultural economic system in the United States. The control variables in the system are the farm policy variables - loan rates, target prices and acreage set-aside levels - for feed grains, wheat and cotton. The state variables in the system are commodity supplies, prices and utilization, as well as aggregate values for production expenses, government expenditures and cash receipts.

The performance measure for control theory is similar to the objective function for programming models. For farm policy analysis the performance measure is a mathematical statement of the trade-offs, both explicit and implicit, between the primary interest groups - farmers, consumers and taxpayers. The variables included in the performance measure are: realized net farm income, net income for livestock producers, total consumer's expenditures for food, Commodity Credit Corporation (CCC) expenditures for storage and interest charges, and ending year carryovers for feed grains, wheat and cotton.

The functional form of the performance measure developed in the thesis is a complete generalization and improvement of the quadratic preference function introduced by Theil (1965). The quadratic preference function assumes constant weights for positive and negative deviations from the targeted value for each output variable. The new functional form allows the analysts to target output variables in the system within acceptable ranges and provides a weighting procedure that differentiates between positive and negative deviations from the acceptable range. Parameter weights and upper and lower boundary levels (acceptable ranges) for the output variables in the performance measure are synthesized from various sources to demonstrate the use of control theory for analyzing farm policy (Table IV).

Results

Four different farm programs are analyzed using the Control Theory Option in POLYSIM, to demonstrate the uses of the technique for selecting values of particular farm policy variables. The farm programs analyzed are the following: No. 1, a price and income support program; No. 2, a price and income support program with voluntary acreage set-aside; No. 3, a price support and acreage set-aside program with a grain reserve provision; and, No. 4, a price and income support program with voluntary acreage set-aside and increased export demands for feed grains, wheat and cotton during the first year simulated. Each farm program is analyzed for the four year period of 1978-1981.

Target prices and loan rates for corn, wheat and cotton in 1978, 1979, 1980 and 1981 are the control variables for farm program No. 1. The control variables for farm programs No. 2, No. 3, and No. 4 are loan rates and acreage set-aside levels for feed grains (corn), wheat and cotton in 1978, 1979, 1980 and 1981. Farm program No. 3 has in addition to these control variables, a requirement that the CCC must hold 20 million tons of feed grains and 500 million tons of wheat as a grain reserve.

The results from analyzing the four farm programs, identified above, with an optimal control technique indicate that the technqiue can be used for farm policy analysis. The optimal values of the control variables appear to be realistic with respect to the prevailing economic conditions for the farm program being evaluated and the performance measure used in the analysis. The optimal loan rates for corn in farm program No. 1 are: \$2.26, \$2.27, \$2.34 and \$2.47 per bushel for 1978, 1979, 1980 and 1981, respectively (Table XIV). The optimal target prices in 1980 and 1981 for corn, wheat and cotton in farm program No. 1 are set at their respective lower boundaries in an attempt to reduce the deficiency payments for these crops since total government payments exceeded the upper boundary level of \$3,700 million for the last three years simulated.

The optimal values for the acreage set-aside levels of feed grains, wheat and cotton in farm program No. 2 are set with respect to several constraints. The acreage set-aside levels for wheat are set equal to the upper boundary constraints in the first three years simulated in an effort to reduce ending year carryovers, and to raise the average market price of wheat. The result is to increase the value of production for wheat and to reduce government deficiency payments for wheat farmers.

A similar explanation can be used to explain the optimal levels of acreage set-aside for cotton. However, the optimal acreage set-aside levels for feed grain in program No. 2 are set at about two thirds of their upper boundary constraints (Table XV). Higher levels of set-aside for corn would have caused corn prices to increase, thus leading to reductions in livestock production and increases in consumer food costs.

Farm program No. 3 includes a hypothetical grain reserve provision that requires the CCC to hold 20 million tons of feed grains and 500 million bushels of wheat. The control mechanism is used to determine the optimal values for loan rates and acreage set-asides of feed grains, wheat and cotton that maximize the performance measure and encourage the CCC to hold exactly the desired reserves. The acreage set-aside levels for wheat and cotton are set to their maximum levels (24. and 3.2 million acres, respectively) in all four years in an attempt to increase market prices and reduce the ending year carryovers for these crops. The set-aside values for feed grains (12, 21, 28 and 32 million acres in 1978, 1979, 1980 and 1981, respectively) are set just high enough to hold ending year stocks within the acceptable range specified in the performance measure (Table XVI). The optimal loan rates for corn ($1.80, $1.94, $2.10 and $2.18 over the 1978-1981 period) and for wheat ($2.23, $2.26, $2.44 and $2.46 in 1978-1981) are set at levels that do not invoke the release or acquisition rules for the CCC, thus causing the CCC to hold exactly the desired level of reserves.

The provisions in farm program No. 4 are the same as those in program No. 2; however, the excess supply situation in the latter is reduced by predetermining exports for feed grains, wheat, and cotton at relatively high levels during the first year simulated. The carryovers for the three crops are reduced in 1978 due to the high export levels thus reducing the need for acreage set-aside. The acreage set-aside levels for feed grains and cotton are less than 1.0 million acres in 1978, for farm program No. 4 while they are set at 10 million acres and 3.2 million acres, respectively, in 1978 for program No. 2 (Table XVII). The acreage set-aside levels for feed grains in 1979, 1980 and 1981 are set higher for program No. 4 than No. 2 in an effort to maintain carryovers within the acceptable ranges in the performance measure by removing the effects of the supply response for feed grains to the higher corn prices in 1978.

Farm program No. 4 is quite interesting in that the complexities of the program demonstrate how the longer run implications of the control variables are considered in selecting values for the farm policy variables. The acreage set-aside levels of wheat in 1978, 1979 and 1980 are about equal to the upper boundary constraints even though ending year carryovers for these years are about equal to the lower level of the acceptable range for wheat carryover. The reason for this is that the maximum level of wheat set-aside in 1981 is not large enough to hold carryovers in 1981 to the acceptable range of 1200 million bushels. So by restricting harvested acreage in 1979 and 1980 the level of beginning year stocks in 1981 is reduced, thus reducing the penalty in 1981 for carryovers greater than 1200 million bushels (Table XVII).

Farm program No. 1 is solved a second time to demonstrate the sensitivity of the optimal solution to changes in the parameter weights used in the performance measure. The parameter weights for consumer's food expenditures, total government payments and CCC storage and interest costs are increased in absolute terms. The results of the analysis indicate that the optimal values of the control variables are quite sensitive to the value of the parameter weights in the performance measure.

Limitations of Using Control Theory for Farm Policy Analysis

The primary limitation to using optimal control techniques for farm policy analysis is the need for a performance measure that incorporates the goals of farmers, consumers and taxpayers. Hopefully the functional form for the performance measure, developed in this study, provides a framework around which policy analysts can develop more meaningful performance measures in the future. The problem of selecting values for the parameters in the performance measure may be eased in the future as control theory is used more widely for farm policy analysis.

Another limitation to using optimal control techniques for policy analysis is that the analyst must have a mathematical model of the particular farm sector to be controlled. This limitation may be an asset since the analyst must become very familiar with the system to be controlled to build a mathematical model of the system. So the analysts may be able to more accurately identify the variables to be controlled and the critical output variables to be included in the performance measure.

Limitations to the present application of control theory are the following: the weights used in the performance measure are not the true values but feasible values that demonstrate the technique, the parameter weights in the performance measure are not discounted for time, the POLYSIM response parameters (elasticities) may not be the true values, and the July 1977 CED, USDA baseline may not be correct with respect to the projections of supply and utilizations for the commodities in the model. In view of these limitations, the values of the control variables reported in the study should not be considered to be the optimal values for the policy variables but examples of the type of information one can obtain by applying control theory techniques to farm policy analysis.

Conclusions

In conclusion, this study demonstrates that an optimal control technique can be used for analyzing farm policy. The values of the farm policy variables selected by the control mechanism appear to be reasonable with respect to the prevailing economic conditions, economic theory, and the performance measure used in the analysis. Results reported in the study indicate that the control mechanism selects values for the control variables in a simultaneous fashion, with respect to the short-run and longer-run effects on the state variables. The ability of the control mechanism to account for the total impact on the performance criteria over the planning period can not be duplicated with the use of simulation alone.

Future Uses for the Control Theory Option in POLYSIM

In the future, work needs to be done to improve the parameter weights used in the performance measure. This is an important area since the results of solving farm program No. 1 using two different sets of parameter weights for the performance measure indicate that the optimal values of loan rates and target prices are sensitive to the values of the parameter weights in the performance measure. The values for the parameter weights may best be developed from working directly with farm policy decision makers. The policy makers could specify a set of parameter weights, and after evaluating the results of the analysis modify the parameter weights and repeat the analysis. The process could be repeated several times until the policy maker fully understood the meaning of the parameter weights and felt certain of the values for the parameter weights.

Another area for future applications of the Control Theory Option in the model is to use the model as a one (or two) year planning model. The model would determine the optimal values for the farm policy variables in the following year, based on the prevailing economic environment in the current year and the farm policy variables available for the Secretary of Agriculture to adjust. Also, the control theory model could be stated in a stochastic mode by selecting random values for crop yields and export demands and then determining the optimal values for the farm policy variables. Probability distributions could then be constructed for the optimal values of the control variables selected by the control mechanism and for the state variables in the model.

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APPENDIX A

LISTING AND DESCRIPTION OF SUBROUTINES ADDED TO POLYSIM FOR THE CONTROL THEORY OPTION

The Control Theory Option in POLYSIM uses the Complex Procedure introduced by Box (1965), to find the set of controls (farm policy variables) that maximize a given performance measure. A Fortran computer program of Box's Complex Procedure (COMPLEX) is available in Kuester and Mize (1973). To incorporate the procedure into POLYSIM, minor changes were made in COMPLEX to simplify data input, output and storage. The individual computer subroutines in COMPLEX are described in this Appendix. (The computer subroutines for POLYSIM are described in Appendix B of Ray and Richardson (1978).) To append the control theory program to POLYSIM, an additional "call" statement is necessary in the POLYSIM MAIN. As described in Appendix B of this study the COMPLEX algorithm is called only when the user specifies the Control Theory Option as part of the usual coding for a POLYSIM run. A listing of the POLYSIM MAIN is presented at the end of this Appendix.

The computer program for using COMPLEX includes the following subroutines: COMPLX, CONSX, CHECK, CENTR, CONSTT, CO718, CO719, CO720, CO721, CO722, CO723, CO724, OBJT, and RANG. POLYSIM is linked to the Complex algorithm through subroutine COMPLX. The data files are passed from POLYSIM to COMPLX by way of the commoned dimension statements in POLYSIM. Subroutine COMPLX has two functions; they are to read the Control Theory Data Cards and to print an output table of the optimal values for the control variables.

The Complex Procedure begins each problem by setting up the initial values for the m control variables. A control problem with m controls has m+1 or k control paths to identify the performance measure. Each of the k control paths has values for each of the m control variables and is considered to be a coordinate for one point on the surface of the performance measure. The control paths are stored in a k by m matrix (X), with the rows containing the k different control paths and the columns containing the values for the m different control variables. The initial control paths can be user supplied or they can be random values, uniformly distributed between the respective lower and upper boundary constraints. The source of the initial control paths is determined by the user, depending upon the data input option specified on the I-O Card (see Appendix B).

Once the X matrix is initialized with starting values for the control variables, each control path is checked to be sure it is admissible (subroutine CHECK). The value of each control variable is compared to its respective lower and upper boundary constraints, provided by the user in subroutine CONSTT and C0718 - C0724, to be sure the control is admissible. If a value is inadmissible, the value is moved inside the violated boundary constraint by a small amount DELTA, say 0.001.

After determining that the control paths are admissible, the performance measure is evaluated for each of the k control paths. The OBJT subroutine contains the performance measure and the call statements for the POLYSIM subroutines so it is called each time a control path is evaluated. To evaluate the initial control paths subroutine OBJT is called k times, each time a different control path is used as input in the POLYSIM model. Simulated values of the output variables are used in the performance measure (Table IV) to obtain a unique real number for evaluating the particular control path. The values of the performance measure are stored in the F array which is a kxl array.

After evaluating the k^{th} initial control path, COMPLEX begins the iterative procedure that leads to the optimal control path for the given performance measure. The first step in each iteration is to identify the control path (row of X) associated with the minimum value of the performance measure, say row i. The control mechanism then replaces the rejected row, i, with a control path that is associated with a higher point on the surface of the performance measure.

New values for control path i are calculated by the following formula:

$$X_{ij}(\text{new}) = \bar{X}_{jc} + \alpha(\bar{X}_{jc} - X_{ij}(\text{old})); \qquad j = 1, 2, \ldots, m$$

where X_{ij}(new) is the new value of control variable j in coordinate or control path i, α is the reflection factor (Box (1965) recommends 1.3), and $\bar{X}_{jc}$ is the centroid for control variable j. The centroid, $\bar{X}_{jc}$, is the average difference between the rejected control variable X_{ij}(old) and the other k-1 values for control variable j. The centroid for each of the m control variables is calculated in subroutine CENTR. The reflection factor, α, is greater than one to insure that the control mechanism searches both sides of the centroid in its approach to the optimal control values.

The new values for the control variables (X_{ij}(new)) are then checked against the lower and upper boundary constraints to insure that the control path is admissible. The value of the performance measure for the i^{th} control path is obtained by using control path i as input in POLYSIM and simulating values for the endogenous variables in the model. If the i^{th} control path is no longer associated with the minimum point on the performance measure the first iteration is complete. However, if the i^{th} control path repeats as the lowest point, new control values are selected checked and evaluated until the i^{th} path is no longer associated with the minimum point on the performance measure.

At the end of each iteration the convergence criteria is checked to see if the performance measure is at a maximum (subroutine CONSX). A maximum is declared if for γ iterations the highest and lowest values of the performance measure remain within β units of each other. (Values for γ and β are provided by the user on the Control Theory Data Cards, see Appendix B.)

By rejecting the control path associated with the minimum value for the performance measure and replacing it with a control path that has a higher performance measure, the procedure will ultimately find the maximum value of the performance measure. The control path associated with the maximum point on the performance measure is considered to be optimal for the given performance measure. To insure that the final solution is at the global maximum for the performance measure the problem should be run several times. Each time a different set of initial control paths should be used so the procedure searches a different set of values for the control variables. If the procedure returns the same answer several times, the analyst can feel fairly certain of having found the global maximum. The four farm programs evaluated for this study were each run three times to determine whether or not a global maximum had been located. For each run the model used a different set of initial control paths and each time the same answer was returned. The number of iterations required to locate an optimum varied from 600 to 1000, depending upon the complexity of the problem.

The boundary constraints for the control variables are critical to the use of the Complex Procedure. The user must provide values for the boundary constraints in the user provided constraint subroutines: C0718, C0719, C0720, C0721, C0722, C0723, and C0724. Based on the farm program being simulated, subroutine CONSTT calls the appropriate constraint subroutine. The names of the farm programs available in the Control Thoery Option and their respective constraint subroutines are presented in Table XIX. For example, when a price support program is being simulated subroutine C0719 is called, or when a price and income support program is being simulated subroutine C0721 is called (Table XIX). The constraint subroutines listed in this Appendix use the boundary constraints presented in Tables I, II, and III. The lower boundary constraints are in array G and the upper boundary constraints are in array H. For each farm program the order of the control variables in arrays G and H is the same as the order in array X, where the values of the control variables are stored. The names of the control variables, used for each of the seven constraint subroutines (farm programs) are presented in Table XIX. The order of the control variables in Table XIX is the order used in array G, H, and X for each of the constraint subroutines.

The order of the control variables for each farm program (Table XIX) is stored on a direct access disk to reduce the data cards needed for the Control Theory Option in POLYSIM. A Fortran program, BOXFILE, is used to store information for the order of the control variables on disk. A listing of BOXFILE is included at the end of this Appendix. Coding instructions for BOXFILE are included as comment cards at the beginning of the program.

TABLE XIX

THE ORDER OF THE CONTROL VARIABLES USED IN SEVEN FARM PROGRAMS IN POLYSIM

Order Number	Farm Program and Variable Name	Variable Code in POLYSIM
	Voluntary Acreage Set-Aside Program (Subroutine C0718)	
1	Feed grain acreage set-aside m. ac. year 1	1
2	Feed grain acreage set-aside m. ac. year 2	1
3	Feed grain acreage set-aside m. ac. year 3	1
4	Feed grain acreage set-aside m. ac. year 4	1
5	Wheat acreage set-aside m. ac. year 1	3
6	Wheat acreage set-aside m. ac. year 2	3
7	Wheat acreage set-aside m. ac. year 3	3
8	Wheat acreage set-aside m. ac. year 4	3
9	Cotton acreage set-aside m. ac. year 1	6
10	Cotton acreage set-aside m. ac. year 2	6
11	Cotton acreage set-aside m. ac. year 3	6
12	Cotton acreage set-aside m. ac. year 4	6
	Price Support Farm Program (Subroutine C0719)	
1	Wheat loan rate $/bu. year 1	55
2	Wheat loan rate $/bu. year 2	55
3	Wheat loan rate $/bu. year 3	55
4	Wheat loan rate $/bu. year 4	55
5	Corn loan rate $/bu. year 1	54
6	Corn loan rate $/bu. year 2	54
7	Corn loan rate $/bu. year 3	54
8	Corn loan rate $/bu. year 4	54
9	Cotton loan rate $/lb. year 1	56
10	Cotton loan rate $/lb. year 2	56
11	Cotton loan rate $/lb. year 3	56
12	Cotton loan rate $/lb. year 4	56
	Income Support Program (Subroutine C0720)	
1	Wheat target price $/bu. year 1	52
2	Wheat target price $/bu. year 2	52
3	Wheat target price $/bu. year 3	52
4	Wheat target price $/bu. year 4	52
5	Corn target price $/bu. year 1	51
6	Corn target price $/bu. year 2	51
7	Corn target price $/bu. year 3	51
8	Corn target price $/bu. year 4	51

TABLE XIX (CONTINUED)

Order Number	Farm Program and Variable Name	Variable Code in POLYSIM
9	Cotton target price $/lb. year 1	53
10	Cotton target price $/lb. year 2	53
11	Cotton target price $/lb. year 3	53
12	Cotton target price $/lb. year 4	53
	Price Support and Income Support Program (Subroutine C0721)	
1	Wheat loan rate $/bu. year 1	55
2	Wheat loan rate $/bu. year 2	55
3	Wheat loan rate $/bu. year 3	55
4	Wheat loan rate $/bu. year 4	55
5	Corn loan rate $/bu. year 1	54
6	Corn loan rate $/bu. year 2	54
7	Corn loan rate $/bu. year 3	54
8	Corn loan rate $/bu. year 4	54
9	Cotton loan rate $/lb. year 1	56
10	Cotton loan rate $/lb. year 2	56
11	Cotton loan rate $/lb. year 3	56
12	Cotton loan rate $/lb. year 4	56
13	Wheat target price $/bu. year 1	52
14	Wheat target price $/bu. year 2	52
15	Wheat target price $/bu. year 3	52
16	Wheat target price $/bu. year 4	52
17	Corn target price $/bu. year 1	51
18	Corn target price $/bu. year 2	51
19	Corn target price $/bu. year 3	51
20	Corn target price $/bu. year 4	51
21	Cotton target price $/lb. year 1	53
22	Cotton target price $/lb. year 2	53
23	Cotton target price $/lb. year 3	53
24	Cotton target price $/lb. year 4	53
	Voluntary Acreage Set-Aside With Price Supports For Participating Farmers (Subroutine C0722)	
1	Wheat loan rate $/bu. year 1	55
2	Wheat loan rate $/bu. year 2	55
3	Wheat loan rate $/bu. year 3	55
4	Wheat loan rate $/bu. year 4	55
5	Corn loan rate $/bu. year 1	54
6	Corn loan rate $/bu. year 2	54
7	Corn loan rate $/bu. year 3	54
8	Corn loan rate $/bu. year 4	54
9	Cotton loan rate $/lb. year 1	56

TABLE XIX (CONTINUED)

Order Number	Farm Program and Variable Name	Variable Code in POLYSIM
10	Cotton loan rate $/lb. year 2	56
11	Cotton loan rate $/lb. year 3	56
12	Cotton loan rate $/lb. year 4	56
13	Feed grain acreage set-aside m. ac. year 1	1
14	Feed grain acreage set-aside m. ac. year 2	1
15	Feed grain acreage set-aside m. ac. year 3	1
16	Feed grain acreage set-aside m. ac. year 4	1
17	Wheat acreage set-aside m. ac. year 1	3
18	Wheat acreage set-aside m. ac. year 2	3
19	Wheat acreage set-aside m. ac. year 3	3
20	Wheat acreage set-aside m. ac. year 4	3
21	Cotton acreage set-aside m. ac. year 1	6
22	Cotton acreage set-aside m. ac. year 2	6
23	Cotton acreage set-aside m. ac. year 3	6
24	Cotton acreage set-aside m. ac. year 4	6
	Voluntary Acreage Set-Aside With Price and Income Supports-The Agricultural Act of 1977 (Subroutine C0723)	
1	Wheat loan rate $/bu. year 1	55
2	Wheat loan rate $/bu. year 2	55
3	Wheat loan rate $/bu. year 3	55
4	Wheat loan rate $/bu. year 4	55
5	Corn loan rate $/bu. year 1	54
6	Corn loan rate $/bu. year 2	54
7	Corn loan rate $/bu. year 3	54
8	Corn loan rate $/bu. year 4	54
9	Cotton loan rate $/lb. year 1	56
10	Cotton loan rate $/lb. year 2	56
11	Cotton loan rate $/lb. year 3	56
12	Cotton loan rate $/lb. year 4	56
13	Feed grain acreage set-aside m. ac. year 1	1
14	Feed grain acreage set-aside m. ac. year 2	1
15	Feed grain acreage set-aside m. ac. year 3	1
16	Feed grain acreage set-aside m. ac. year 4	1
17	Wheat acreage set-aside m. ac. year 1	3
18	Wheat acreage set-aside m. ac. year 2	3
19	Wheat acreage set-aside m. ac. year 3	3
20	Wheat acreage set-aside m. ac. year 4	3
21	Cotton acreage set-aside m. ac. year 1	6
22	Cotton acreage set-aside m. ac. year 2	6
23	Cotton acreage set-aside m. ac. year 3	6
24	Cotton acreage set-aside m. ac. year 4	6

TABLE XIX (CONTINUED)

Order Number	Farm Program and Variable Name	Variable Code in POLYSIM
	Voluntary Acreage Set-Aside With Income Supports (Subroutine C0724)	
1	Feed grain acreage set-aside m. ac. year 1	1
2	Feed grain acreage set-aside m. ac. year 2	1
3	Feed grain acreage set-aside m. ac. year 3	1
4	Feed grain acreage set-aside m. ac. year 4	1
5	Wheat acreage set-aside m. ac. year 1	3
6	Wheat acreage set-aside m. ac. year 2	3
7	Wheat acreage set-aside m. ac. year 3	3
8	Wheat acreage set-aside m. ac. year 4	3
9	Cotton acreage set-aside m. ac. year 1	6
10	Cotton acreage set-aside m. ac. year 2	6
11	Cotton acreage set-aside m. ac. year 3	6
12	Cotton acreage set-aside m. ac. year 4	6
13	Wheat target price $/bu. year 1	52
14	Wheat target price $/bu. year 2	52
15	Wheat target price $/bu. year 3	52
16	Wheat target price $/bu. year 4	52
17	Corn target price $/bu. year 1	51
18	Corn target price $/bu. year 2	51
19	Corn target price $/bu. year 3	51
20	Corn target price $/bu. year 4	51
21	Cotton target price $/lb. year 1	53
22	Cotton target price $/lb. year 2	53
23	Cotton target price $/lb. year 3	53
24	Cotton target price $/lb. year 4	53

```
C*****************************************************************************
C                             DETERMINISTIC POLYSIM MAIN
C                             CONTROL THEORY OPTION
C*****************************************************************************
C---- LATEST REVISION 9-4-77
      COMMON  /CMAIN3/ SIMNAM(20), NEXOG(180), NFILE(300), DM(7,7),
     1EE(200)
      INTEGER SUMFIL(160), SUMTAB(160,6), SUMF(160)
      COMMON  /CMAIN4/ SUMFIL, SUMTAB, SUMF, NOEXC
      INTEGER FT(90), TITLE(20,20), LABEL(84,33), SKIP(8)
      COMMON  /CMAIN5/ FT, TITLE, LABEL, SKIP, JUMP
      INTEGER DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT, SUPSOY, A73
      COMMON  /CMAIN6/ DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT,
     1SUPSOY, A73, IKEY1, IKEY2
      COMMON  /CMAIN7/ NFILEE(40), NCFILE(180), NDUM(180), ICFILE(200)
      COMMON  /CMAINB/ IFI(50), IF2(50), A(20), TREND(80), NAR,
     1FGYDEV,FGEDEV,WHYDEV,WHEDEV,SYYDEV,SYEDEV,CTYDEV,CTEDEV
      COMMON  /CMAINC/ LFM, NOSIM, NPRB, NOBS, NPRC, NH1, NH2, NH3, NH4
      COMMON  /CMAIND/ LOAN, FGEXP, FPRIC, WPLCP1, IEN, DUM(14,3)
      COMMON  /CMAINF/ IFSTYR, NOB, ISIMND, IMONTH, IDAY, IBASYR, IOBJT
      COMMON /CMAING/ NBC, NE, NADJ, NEX, NPRE, NERD, NESTOR, NFACT,
     1  NADJST, KING, NPROM, NDIVAC, NOTARG, NOALL, NLOAN, NDIV, NEXP,
     2 NOACRE, NYIELD, NPROD, IVARE, INDXX, NFSTST, NPART, NCONST
      COMMON /CMAINH/ NOPOL, NEPOL, NRO, IDROP, LASTYR ,ACRE(14,12)
      COMMON /CMAINI/ YIELD(16,4),IAJLOT, ADJTG, IZ, IT, IX, IST
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LG, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /CSTOC/  YIELDX(4,4), EXPORT(4,4), AMIN(80), AMODE(80),
     1AMAX(80), PERC(80), IDATA(3,100),CDATA(14,100),INTER, NTER,AMATRX(
     28,8) ,IEND1, IEND2,IST1,IST2,IEX2
      COMMON /CUMUL/ PVAL(80,12) ,ISTART,IEND
      DEFINE FILE 10(999,90,U,JNEXT)    ,11(999,580,U,JNEX)
      DEFINE FILE  13(301,250,U,JN1),14(14,600,U,JN2)
      DEFINE FILE  16(100,60,U,JCOM)
12345 FORMAT(1H0, 'POLYSIM    MAIN    BEGUN')
      WRITE(8,12345)
      NAR=5999979
      CALL INT1
      DO 1900  LFM=1,100
  200 CALL INITAL
      IF(NPRB.NE.0) CALL TAB2
      NPRB=0
      CALL INT2
      IF (IFLAG.EQ.5) GO TO 200
      IF(IKEY1.NE.0) CALL COMPLX
      DO 2000 INTER=1,IHOLD1
      NTER=INTER
C-----SIMULATION LOOP
      DO 1000 I= 3  ,NOBS
      J=I-1
      CALL SETUP
      CALL LVSK
      CALL TGTP77
      CALL ADJLOT
      CALL CROPQ
      CALL FDGR
      CALL WHEAT
      CALL SOYB
      CALL COTTON
      CALL FED2
      CALL RECPTS
      CALL GOVP
      CALL TOTALS
      CALL CONS
 1000 CONTINUE
 2000 CONTINUE
      CALL TAB1
      CALL TAB2
      CALL TAB3
 1900 CONTINUE
        STOP
       END
C*****************************************************************************
      SUBROUTINE COMPLX
C*****************************************************************************
C/////  THIS VERSION OF BOX CONTAINS COMMON STATEMENTS AND RANG AS A
C/////  RANDOM NO. GENERATOR FOR THE RANDOM POINTS ON THE SURFACE.
C/////  ALSO, THE VERSION HAS THE PROVISION FOR THE USER TO PROVIDE
C/////  THE POINTS FOR ALL OF THE INITIAL POINTS ON THE SURFACE.
C/////  REVIZED BY JWR 6/77.
      COMMON  /CMAIN3/ SIMNAM(20), NEXOG(180), NFILE(300), DM(7,7),
     1EF(200)
      INTEGER FT(90), TITLE(20,20), LABEL(84,33), SKIP(8)
      COMMON  /CMAIN5/ FT, TITLE, LABEL, SKIP, JUMP
      INTEGER DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT, SUPSOY, A73
      COMMON  /CMAIN6/ DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT,
     1SUPSOY, A73, IKEY1, IKEY2
      COMMON  /CMAIND/ LOAN, FGEXP, FPRIC, WPLCP1, IEN, DUM(14,3)
      COMMON /CMAINH/ NOPOL, NEPOL, NRO, IDROP, LASTYR ,ACRE(14,12)
      COMMON /CMAINI/ YIELD(16,4),IAJLOT, ADJTG, IZ, IT, IX, IST
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LG, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /CSTOC/  YIELDX(4,4), EXPORT(4,4), AMIN(80), AMODE(80),
     1AMAX(80), PERC(80), IDATA(3,100),CDATA(14,100),INTER, NTER,AMATRX(
     28,8) ,IEND1, IEND2,IST1,IST2,IEX2
      COMMON  /CMAINB/ IFI(50), IF2(50), A(20), TREND(80), NAR,
     1FGYDEV,FGEDEV,WHYDEV,WHEDEV,SYYDEV,SYEDEV,CTYDEV,CTEDEV
      COMMON  /CMAINC/ LFM, NOSIM, NPRB, NOBS, NPRC, NH1, NH2, NH3, NH4
      INTEGER GAMMA
      COMMON  /BMAIN1/  ITMAX ,IQ, R(60,60) , NO, ALPHA, BETA, GAMMA
      INTEGER   BEG,END, BEG2
      COMMON  /BMAIN2/ IBASE,    DELTA, KODE, IPRINT ,IC ,BEG,END,BEG2
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
      COMMON  /BMAIN4/ NBFILE(99)
      DIMENSION ANAM(5)
    1 FORMAT(I1,9X,F10.0,3I4)
    2 FORMAT(I1,9X,3F10.0,2I4)
    4 FORMAT (8F10.4)
    3 FORMAT (' ',I4,10(10F10.5,/))
    6 FORMAT (' ',T5,I4,T12,5A4,T40,3(F10.4,5X))
    7 FORMAT('0',T8,'J',T17,'VARIABLE NAME',T42,'X(I,J)',T59,'G(J)',
     1 T74,'H(J)')
    8 FORMAT(' ',//, ' THE USER PROVIDED VALUES FOR POINTS 1-K')
   10 FORMAT (1H1,//,18X,24HCOMPLEX PROCEDURE OF BOX)
   11 FORMAT(' ',/,T3,'PARAMETERS',/
     1,T5,'NO. OF EXPLICIT CONSTRAINTS(N) =',I4,/
     1,T5,'NO. OF IMPLICIT CONSTRAINTS(IC =',I4,/
     3,T5,'NO. OF TOTAL    CONSTRAINTS(M) =',I4,//
     3,T5,'NO. OF POINTS ON SURFACE(K)    =',I4,/
     3,T5,'NO. OF MAXIMUM ITERATION(ITMAX)=',I4,/
     3,T5,'NO. OF REPEAT ITERATIONS(GAMMA)=',I4,//
     3,T5,'REFLECTION FACTOR      (ALPHA)   =', F6.2,/
     3,T5,'DEGREE OF ACCURACY     (BETA)    =', F6.2    ,/
     3,T5,'WITHIN BOUNDS ADJUST (DELTA)     =', F8.4,/        )
   12 FORMAT (//,2X,14HRANDOM NUMBERS)
   13 FORMAT (/,3(2X,2HR(,I2,1H,,I2,4H) = ,F6.4,2X))
   14 FORMAT (///,2X,30HFINAL VALUE OF THE FUNCTION = ,E20.8)
```

```
   15 FORMAT (//,2X,14HFINAL X VALUES)
   16 FORMAT (/,2X,2HX(,I2,4H) = ,4X,5A4,F30.10,10X,I4)
   17 FORMAT (///,2X,38HTHE NUMBER OF ITERATIONS HAS EXCEEDED ,I4,10X,
     118HPROGRAM TERMINATED)
   18 FORMAT(' ', ' RANDOM NO. SEED IS = ',2X,F12.0  ,/)
   19 FORMAT('1',' JOB TERMINATED BECAUSE CARDS FOR COMPLX ARE OUT OF OR
     1DER')
      NI = 5
      NC = 6
C     PULL THE NBFILE FROM DISK BASED ON PROGRAM TO ANALYZE.
      IF(DIVAC.NE.C.AND.LCAN.EQ.0.AND.TARGET.EQ.0) KNB=718
      IF(DIVAC.EQ.C.AND.LCAN.NE.0.AND.TARGET.EQ.0) KNB=719
      IF(DIVAC.EQ.C.AND.LCAN.EQ.0.AND.TARGET.NE.0) KNB=720
      IF(DIVAC.EQ.C.AND.LOAN.NE.0.AND.TARGET.NE.0) KNB=721
      IF(DIVAC.NE.C.AND.LCAN.NE.0.AND.TARGET.EQ.0) KNB=722
      IF(DIVAC.NE.C.AND.LOAN.NE.0.AND.TARGET.NE.0) KNB=723
      IF(DIVAC.NE.C.AND.LCAN.EQ.0.AND.TARGET.NE.0) KNB=724
      READ(10' KNB) (NBFILE(L),L=1,90)
      WRITE(6,3) KNB
C     READ THE I-O CARD
      READ(5,1) IKO, ANAR,          IPRINT, NDEBUG, IBASE
      IF(IKO.NE.7) GO TO 29
C     READ THE PARAMETER CARD.
      READ(5,2) IKO, ALPHA, BETA, DELTA, GAMMA, ITMAX
      IF(IKO.NE.8) GO TO 29
      GO TO 32
   29 WRITE(6,19)
      STOP
   32 NAR=ANAR
C     BASED ON POLICY BEING RUN SET-UP THE NO. OF EXPLICIT & IMPLICIT
      BEG=1
      END=NBFILE(1)-2
C     N IS NO. OF EXPLICIT IND. VARIABLES.                        60
      N=END
C     M IS NO. OF SETS OF CONSTRAINTS IMPL. & EXPL. IN G&H.       99 MAX
      M=NBFILE(2)-2
      BEG2=END+1
C     IC IS NO. OF IMPLICIT CONSTRAINTS IC=M-N.                   M-N    .
      IC=M-N
C     K IS NO. OF POINTS ON THE COMPLEX.                          30 MAX
      K=END+ 1
C     PRINT THE PARAMETER SUMMARY
      WRITE (NO,010)
      WRITE(6,11) N,IC,M,K,ITMAX,GAMMA,ALPHA,BETA,DELTA
C      ZERO OUT THE X MATRIX
      DO 41 II=1,K
      DO 31 J=BEG,M
   31 X(II,J) = 0.0
   41 CONTINUE
C     PUT THE BASELINE DATA IN THE FIRST POINTS ARRAY STORAGE.
      IF(IBASE.NE.0) GO TO 40
      DO 35 J=BEG,M
      IO=NBFILE(J+2)
   35 X(1,J)=EXOG(3,IO)
C           READ THE USER SUPPLIED VALUES FOR X FOR POINTS 1 THROUGH K,
C           THE STARTING VALUE CARDS.
   40 IF(IBASE.NE.1) GO TO 450
      WRITE(6,8)
      DO 425 L=1,K
      READ(5,4) (X(L,J),J=BEG,END)
  425 WRITE(6,3) L, (X(L,J),J=BEG,END)
      GO TO 210
  450 CONTINUE
      I=1
      CALL CONSTT
      WRITE(6,7)
      DO 250 J=BEG,M
      L=J+2
      READ(10' NEXOG(NBFILE(L)) ) A9,(ANAM(L1),L1=1,5)
  250 WRITE(6,6) J,(ANAM(L1),L1=1,5), X(1,J),G(J),H(J)
      IF(IBASE.EQ.3) GO TO 210
      DO 100 II=1,K
      DO 100 JJ=BEG,END
      RAN1 = RANG(NAR)
      R(II,JJ) = RAN1
  100 CONTINUE
      WRITE (NO,012)
      WRITE(6,18)ANAR
      DO 200  J=1,K
      WRITE (NO,013) (J, L, R(J,L), L= BEG,END)
  200 CONTINUE
  210 CONTINUE
      CALL CONSX
      IF (IQ-ITMAX) 20,20,30
   20 WRITE (NO,014) F(IEV2)
      WRITE (NO,015)
      GO TO 999
   30 WRITE (NO,017) ITMAX
      DO 850 I=1,K
      DO 900 J=BEG,M
      L=J+2
      READ(10' NEXOG(NBFILE(L)) ) A9,(ANAM(L1),L1=1,5)
      WRITE (NO,016) J,(ANAM(L1),L1=1,5), X(I,J) ,I
  900 CONTINUE
  850 CONTINUE
C     STORE THE POINTS ON DISK FOR COLD START .'0003' IN CC 28-32 I-O CO
      DO 875 J=1,M
  875 WRITE(16' J) (X(I,J),I=1,K)
  999 CONTINUE
      DO 300 J=BEG,M
      L=J+2
      READ(10' NEXOG(NBFILE(L)) ) A9,(ANAM(L1),L1=1,5)
      WRITE (NO,016) J,(ANAM(L1),L1=1,5), X(IEV2,J)
  300 CONTINUE
C     PUT THE VALUES OF THE OPTIMAL SOLUTION INTO THE EXOG ARRAY
      I=2
      DO 110 ICOL=BEG,M
      IOJ=NBFILE(ICOL+1)
      IO=NBFILE(ICOL+2)
      IF(IO.NE.IOJ) I=2
      I=I+1
  110 EXOG(I,IO) = X(IEV2,ICOL)
      RETURN
      END
C***********************************************************************
      SUBROUTINE CONSX
C***********************************************************************
      COMMON  /CMAIN3/ SIMNAM(20), NEXOG(180), NFILE(300), DM(7,7),
     1FE(200)
      INTEGER FT(90), TITLE(20,20), LABEL(84,33), SKIP(8)
      COMMON  /CMAIN5/ FT, TITLE, LABEL, SKIP, JUMP
      INTEGER DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT, SUPSOY, A73
      COMMON  /CMAIN6/ DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT,
     1SUPSOY, A73, IKEY1, IKEY2
      COMMON  /CMAINC/ LFM, NOSIM, NPRB, NOBS, NPRC, NH1, NH2, NH3, NH4
      COMMON  /CMAIND/ LOAN, FGEXP, FPRIC, WPLCP1, IEN, DUM(14,3)
      COMMON /CMAINH/ NCPCL, NEPOL, NRO, IDROP, LASTYR ,ACRE(14,12)
      COMMON /CMAINI/ YIELD(16,4),IADJOT, ADJTG, IZ, IT, IX, IST
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /CSTCC/  YIELDX(4,4), EXPORT(4,4), AMIN(80), AMODE(80),
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     1AMAX(30), PERC(60), IDATA(3,100),CDATA(14,100),INTER, NTER,AMATRX(
     28,8) ,IEND1, IEND2,IST1,IST2,IEX2
      INTEGER GAMMA
      COMMON  /BMAIN1/  ITMAX ,IQ, F(60,60) , NO, ALPHA, BETA, GAMMA
      INTEGER   BEG,END, BEG2
      COMMON  /BMAIN2/ IBASE,     DELTA, KODE, IPRINT ,IC ,BEG,END,BEG2
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
      COMMON  /BMAIN4/ NBFILE(99)
    1 FORMAT(' ',' GOING TO 170 FOR TIME NO. ',I4,3E15.5)
   16 FORMAT(' ','  STORED K POINTS ON DISK FOR ITERATION NO. ',I4)
   17 FORMAT(' ','  DATA FOR K POINTS READ FROM UNIT 16')
  018 FORMAT (//,2X,30HCOORDINATES OF INITIAL COMPLEX)
  019 FORMAT (/,5(1X,2HX(,I2,1H,,I2,4H) = ,  E13.6))
  021 FORMAT (/,2X,22HVALUES OF THE FUNCTION )
   22 FORMAT (  /,5(1X,2HF(,I2,4H) = ,  E13.6))
  023 FORMAT (//,2X,17HITERATION NUMBER ,I5)
  024 FORMAT (/,2X,30HCOORDINATES OF CORRECTED POINT)
  025 FORMAT (/,2X,27HCOORDINATES OF THE CENTROID)
  026 FORMAT (/,5(1X,2HX(,I2,6H,C) = ,  E13.6))
 1234 FORMAT(' ',2X, 'SUBROUTINE CONSX')
      IF(NDEBUG.NE.0) WRITE(6,1234)
C     IQ     = ITERATION INDEX
C     IEV1   = INDEX OF POINT WITH MINIMUM FUNCTION VALUE.
C     IEV2   = INDEX OF POINT WITH MAXIMUM FUNCTION VALUE.
C     I      = POINT INDEX.
C     KODE   = CONTROL KEY USED TO DETERMINE IF IMPLICIT CONSTRAINTS
C              ARE PROVIDED.
C     K1     = DO LOOP LIMIT
      IQ = 1
      KODE = 0
      IF (M-N) 20,20,10
   10 KODE = 1
   20 CONTINUE
C     CALCULATE COMPLEX POINTS AT RANDOM FROM UNIFORMLY DISTRIBUTED
C     NOS. & THE BOUNDARY CONSTRAINTS.
      IF(IBASE.EQ.1 .OR. IBASE.EQ.3) GO TO 61
      IROW1 = 2
      IF(IBASE.EQ.2) IROW1 = 1
      DO 65 II=IROW1,K
      DO 50 J=BEG,END
      I = II
      CALL CONSTT
      X(II,J) = G(J) + R(II,J)*(H(J)-G(J))
   50 CONTINUE
C     CHECK THE VALUES OF EXPLICIT VARIABLES
      DO 350 J=BEG,END
      IF(X(I,J)- G(J)) 320,320,330
  320 X(I,J) = G(J) + DELTA
      GO TO 350
  330 IF( H(J)-X(I,J)) 340,340,350
  340 X(I,J) = H(J)- DELTA
  350 CONTINUE
      CALL CONSTT
      K1 = II
      CALL CHECK
      IF (II-2) 51, 51, 55
   51 IF (IPRINT) 52, 65, 52
   52 WRITE (NO,018)
      IQ = 1
      WRITE (NO,019) (IC, J, X(IQ,J), J= BEG,END)
   55 IF (IPRINT) 56, 65, 56
   56 WRITE (NO,019) (II, J, X(II,J), J= BEG,END)
   65 CONTINUE
      GO TO 69
C        ENTER HERE IF THE USER HAS PROVIDED X VALUES FOR 1 THROUGH K
C        CALL CONST TO CALCULATE OTHER X VALUES & GET READY TO CALL FUNC
   61 CONTINUE
      IF(IBASE.EQ.1) GO TO 63
C     READ THE K POINTS FROM DISK, UNIT 16.
      DO 62 L=1,M
   62 READ(16' L) (X(IKK,L),IKK=1,K)
      WRITE(6,17)
   63 CONTINUE
      WRITE (NO,018)
      DO  64  I=1,K
      CALL CONSTT
      K1=I
      CALL CHECK
      WRITE (NO,019) (I , J, X(I ,J), J= BEG,END)
   64 CONTINUE
   69 K1 = K
      DO 70 I=1,K
      CALL OBJT
   70 CONTINUE
      KOUNT = 1
      IA = 0
      IF (IPRINT) 72, 80, 72
   72 WRITE (NO,021)
      WRITE (NO,022) (J, F(J), J=1,K)
C
C        THE PROGRAM WORKS BETWEEN HERE AND '240 RETURN'
C        UNTIL AN OPTIMUM IS REACHED.
C
   80 IEV1 = 1
C     FIND THE INDEX FOR THE MINIMUM OF F(I) ,I=1,K
      DO 100 ICM=2,K
      IF (F(IEV1)-F(ICM)) 100,100,90
   90 IEV1 = ICM
  100 CONTINUE
C     FIND POINT WITH HIGHEST FUNCTION VALUE
      IEV2 = 1
      DO 120 ICM=2,K
      IF (F(IEV2)-F(ICM)) 110,110,120
  110 IEV2 = ICM
  120 CONTINUE
C
C     CHECK CONVERGENCE CRITERIA
C
      IF (F(IEV2)-(F(IEV1)+BETA)) 140,130,130
  130 KOUNT = 1
      GO TO 150
  140 KOUNT = KOUNT + 1
      IF (KOUNT-GAMMA) 150,240,240
C
C     REPLACE POINT WITH LOWEST FUNCTION VALUE
  150 CONTINUE
      CALL CENTR
      DO 160  JJ=BEG,END
  160 X(IEV1,JJ) = (1.0+ALPHA)*(XC(JJ))-ALPHA*(X(IEV1,JJ))
      I = IEV1
      CALL CHECK
      CALL OBJT
      IEV3 = IEV2
      ICOUNT=0
  170 CONTINUE
C
C     REPLACE NEW POINT IF IT REPEATS AS LOWEST FUNCTION VALUE
C
C     FIND THE INDEX FOR THE F() WITH THE MINIMUM VALUE.
      ICOUNT=1+ ICOUNT
      IEV2 = 1
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      DO 190 ICM=2,K
      IF (F(IEV2)-F(ICM)) 190,190,180
  180 IEV2 = ICM
  190 CONTINUE
      IF (IEV2-IEV1) 220,200,220
  200 DO 210 JJ=BEG,END
      L=K/4
      IF(K.GT.2 .AND. ICOUNT.GE.L) XC(JJ)=X(IEV3,JJ)
      X(IEV1,JJ)=(X(IEV1,JJ) + XC(JJ))/2.0
  210 CONTINUE
      I = IEV1
      CALL CHECK
      CALL OBJT
      IF(IPRINT) 480,485,480
  480 WRITE(6,1) ICOUNT,F(IEV1),F(IEV2) ,F(IEV3)
      WRITE (NO,022) (I, F(I), I=BEG,K)
  485 CONTINUE
C     IF(ICOUNT.EQ. K) GO TO 220
      GO TO 170
  220 CONTINUE
      IF (IPRINT) 230, 228, 230
  230 WRITE (NO,023) IC
      WRITE (NO,024)
      WRITE (NO,019) (IEV1, JC, X(IEV1,JC), JC= BEG,END)
      WRITE (NO,021)
      WRITE (NO,022) (I, F(I), I=BEG,K)
      WRITE (NO,025)
      WRITE (NO,026) (JC, XC(JC), JC=BEG,END)
  228 IC = IC + 1
C       STORE THE X MATRIX ON DISK AT THE END OF EVERY TENTH ITERATION
C        FOR A COLD START, '0003' IN CC 28-32 OF I-O CARD.
      IF(MOD(IQ,10).NE.0) GO TO 239
      DO 238 L=1,M
  238 WRITE(16' L) (X(IKK,L),IKK=1,K)
      WRITE(6,16) IQ
      WRITE (NO,022) (I, F(I), I=BEG,K)
  239 IF (IQ-ITMAX) 80,80,240
  240 RETURN
      END
C***********************************************************************
      SUBROUTINE CHECK
C***********************************************************************
      COMMON  /CMAIN3/ SIMNAM(20), NEXOG(180), NFILE(300), DM(7,7),
     1EE(200)
      INTEGER FT(90), TITLE(20,20), LABEL(84,33), SKIP(8)
      COMMON  /CMAIN5/ FT, TITLE, LABEL, SKIP, JUMP
      INTEGER DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT, SUPSOY, A73
      COMMON  /CMAIN6/ DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT,
     1SUPSOY, A73, IKEY1, IKEY2
      COMMON  /CMAINC/ LFM, NOSIM, NPRB, NOBS, NPRC, NH1, NH2, NH3, NH4
      COMMON  /CMAIND/ LOAN, FGEXP, FPRIC, WPLCP1, IEN, DUM(14,3)
      COMMON /CMAINH/ NCPOL, NEPOL, NRO, IDROP, LASTYR ,ACRE(14,12)
      COMMON /CMAINI/ YIELD(16,4),IAJLOT, ADJTG, IZ, IT, IX, IST
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LC, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /CSTCC/  YIELDX(4,4), EXPORT(4,4), AMIN(80), AMODE(80),
     1AMAX(80), PERC(80), IDATA(3,100),CDATA(14,100),INTER, NTER,AMATRX(
     28,8) ,IEND1, IEND2,IST1,IST2,IEX2
      INTEGER GAMMA
      COMMON  /BMAIN1/  ITMAX ,IQ, R(60,60) , NG, ALPHA, BETA, GAMMA
      INTEGER    BEG,END, BEG2
      COMMON  /BMAIN2/ IBASE,    DELTA, KODE, IPRINT ,IC ,BEG,END,BEG2
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
      COMMON  /BMAIN4/ NBFILE(99)
    1 FORMAT( ' ',2I4,3F15.4)
 1234 FORMAT(' ',2X, 'SUBROUTINE CHECK')
      IF(NDEBUG.NE.0) WRITE(6,1234)
      ICOUNT=0
   10 KT = 0
      ICOUNT=1+ ICOUNT
      CALL CONSTT
C     CHECK AGAINST EXPLICIT CONSTRAINTS
      DO 50 J=BEG,END
      IF (X(I,J)-G(J)) 20,20,30
   20 X(I,J) = G(J) + DELTA
      GO TO 50
   30 IF (H(J)-X(I,J)) 40,40,50
   40 X(I,J) = H(J) - DELTA
   50 CONTINUE
      IF (KODE) 110,110,60
C     CHECK AGAINST THE IMPLICIT CONSTRAINTS
   60 NN = END + 1
      DO 100 J=NN,M
      CALL CONSTT
      IF(NDEBUG.NE.0) WRITE(6,1) J,I,X(I,J),G(J), H(J)
      IF (X(I,J)-G(J)) 80,70,70
   70 IF (H(J)-X(I,J)) 80,100,100
   80 IEV1 = I
      KT = 1
      CALL CENTR
      DO 90 JJ=BEG,END
      X(I,JJ) = (X(I,JJ) + XC(JJ))/2.0
   90 CONTINUE
  100 CONTINUE
      IF (KT) 110, 110, 10
  110 RETURN
      END
C***********************************************************************
      SUBROUTINE CENTR
C***********************************************************************
      COMMON  /CMAIN3/ SIMNAM(20), NEXOG(180), NFILE(300), DM(7,7),
     1EE(200)
      INTEGER FT(90), TITLE(20,20), LABEL(84,33), SKIP(8)
      COMMON  /CMAIN5/ FT, TITLE, LABEL, SKIP, JUMP
      INTEGER DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT, SUPSOY, A73
      COMMON  /CMAIN6/ DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT,
     1SUPSOY, A73, IKEY1, IKEY2
      COMMON  /CMAINC/ LFM, NOSIM, NPRB, NOBS, NPRC, NH1, NH2, NH3, NH4
      COMMON  /CMAIND/ LOAN, FGEXP, FPRIC, WPLCP1, IEN, DUM(14,3)
      COMMON /CMAINH/ NCPOL, NEPOL, NRO, IDROP, LASTYR ,ACRE(14,12)
      COMMON /CMAINI/ YIELD(16,4),IAJLOT, ADJTG, IZ, IT, IX, IST
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /CSTCC/  YIELDX(4,4), EXPORT(4,4), AMIN(80), AMODE(80),
     1AMAX(80), PERC(80), IDATA(3,100),CDATA(14,100),INTER, NTER,AMATRX(
     28,8) ,IEND1, IEND2,IST1,IST2,IEX2
      INTEGER    BEG,END, BEG2
      COMMON  /BMAIN2/ IBASE,    DELTA, KODE, IPRINT ,IC ,BEG,END,BEG2
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
      COMMON  /BMAIN4/ NBFILE(99)
 1234 FORMAT(' ',2X, 'SUBROUTINE CENTR')
      IF(NDEBUG.NE.0) WRITE(6,1234)
      DO 20  J=BEG,END
      XC(J) = 0.0
      DO 10  IL=1,K1
   10 XC(J) = XC(J) + X(IL,J)
      RK = K1
   20 XC(J) = (XC(J)-X(IEV1,J))/(RK-1.0)
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```
      RETURN
      END
C*****************************************************************************
      SUBROUTINE OBJT
C*****************************************************************************
      COMMON  /CMAIN3/ SIMNAM(20), NEXOG(180), NFILE(300), DM(7,7),
     1EE(200)
      INTEGER FT(90), TITLE(20,20), LABEL(84,33), SKIP(8)
      COMMON  /CMAIN5/ FT, TITLE, LABEL, SKIP, JUMP
      INTEGER DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT, SUPSOY, A73
      COMMON  /CMAIN6/ DIVAC, TARGET, FREMKT, SUPFG, SUPWHT, SUPCOT,
     1SUPSOY, A73, IKEY1, IKEY2
      COMMON  /CMAINC/ LFM, NOSIM, NPRB, NOBS, NPRC, NH1, NH2, NH3, NH4
      COMMON  /CMAIND/ LOAN, FGEXP, FPRIC, WPLCP1, IEN, DUM(14,3)
      COMMON /CMAINH/ NCPOL, NEPOL, NRO, IDROP, LASTYR ,ACRE(14,12)
      COMMON /CMAINI/ YIELD(16,4),IAJLOT, ADJTG, IZ, IT, IX, IST
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /CSTCC/  YIELDX(4,4), EXPORT(4,4), AMIN(80), AMODE(80),
     1AMAX(80), PERC(80), IDATA(3,100),CDATA(14,100),INTER, NTER,AMATRX(
     28,8) ,IEND1, IEND2,IST1,IST2,IEX2
      COMMON /CRLOAN/ FGEXP1, SYEXP1, WHEXP1, CTEXP1
      INTEGER   BEG,END, BEG2
      COMMON  /BMAIN2/ IBASE,   DELTA, KODE, IPRINT ,IC ,BEG,END,BEG2
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
      COMMON  /BMAIN4/ NBFILE(99)
    1 FORMAT(' ',10(  5F12.2,3X,   5F12.2,/))
    2 FORMAT(' ',' THE VALUE OF THE PEFORMANCE MEASURE = ',I2,F20.1)
 1234 FORMAT(' ',2X, 'SUBROUTINE OBJT')
      IF(NDEBUG.NE.0) WRITE(6,1234)
      IB=I
C     MOVE THE POLICY VARIABLES' VALUES INTO EXOG .
      I=2
      DO 110 ICOL=BEG,M
      IOJ=NBFILE(ICOL+1)
      IO=NBFILE(ICOL+2)
      IF(IC.NE.IOJ) I=2
      I=I+1
  110 EXOG(I,IO) = X(IB,ICOL)
      DO 95 I=3,NOBS
      EXOG(I,61) = EXOG(I,54) * (OLDEXO(I,61) / OLDEXO(I,54) )
      EXOG(I,62) = EXOG(I,54) * (OLDEXO(I,62) / OLDEXO(I,54) )
      EXOG(I,59) = EXOG(I,51) * (OLDEXO(I,59) / OLDEXO(I,51) )
      EXOG(I,60) = EXOG(I,51) * (OLDEXO(I,60) / OLDEXO(I,51) )
   95 CONTINUE
C     SIMULATION LOOP IN POLYSIM.
      DO 1000 I= 3,NOBS
      J= I-1
      CALL SETUP
      CALL LVSK
      CALL TGTP77
      CALL ADJLOT
      CALL CROPO
      CALL FDGR
      CALL WHEAT
      CALL SCYB
      CALL COTTON
      CALL FED2
      CALL RECPTS
      CALL GOVP
      CALL TOTALS
      CALL CONS
 1000 CONTINUE
C     PERFORMANCE MEASURE F(IB) OR IN THE TEXT (J)
C     Y'S  IN 211 - 218          OR J1
C     LB'S IN 225 - 239 ODD      OR J2
C     UB'S IN 226 - 240 EVEN     OR K2
C     -'S  IN 251 - 265 ODD      OR J3
C     I'S  IN 252 - 266 EVEN     OR K3
C     JL'S IN 271 - 278          OR JL
C     JU'S IN 281 - 288          OR JU
      DO 115 I=3,NOBS
      DO 115 J=1,8
      JL=270+J
      JU=280+J
      JP=290+J
      C(I,JP) = 0.0
      C(I,JL) = 0.0
  115 C(I,JU) = 0.0
C     MOVE THE OUTPUT VARIABLES INTO FILES 211 - 218
      DO 120 I=3,NOBS
      C(I,211)= C(I,93)
      C(I,212)= C(I,88) - C(I,86)
      C(I,213)= C(I,100)
      C(I,214)= C(I,096)
      C(I,215)= C(I,202)
      C(I,216)= C(I,041)
      C(I,217)= C(I,042)
      C(I,218)= C(I,044)
  120 CONTINUE
C     COMPLTE THE JL'S AND JU'S
      DO 140 I=3,NOBS
      J2=223
      J3=249
      K2=224
      K3=250
      DO 130 L=1,8
      J1=210+L
      JL=270+L
      JU=280+L
      J2=2+J2
      J3=2+J3
      K2=2+K2
      K3=2+K3
C     PENALTY FOR THE LOWER BOUNDARY BEING VIOLATED, THE JL'S
      IF(C(I,J1) .LT. C(I,J2)) C(I,JL)=C(I,J3)*(ABS (C(I,J1)-C(I,J2)) )
C     PENALTY FOR THE UPPER BOUNDARY BEING VIOLATED, THE JU'S
      IF(C(I,J1) .GT. C(I,K2)) C(I,JU)=C(I,K3)*(ABS (C(I,J1)-C(I,K2)) )
      IF(NDEBUG) 130,130,129
  129 WRITE(6,1) C(I,J1),C(I,J2),C(I,JL),C(I,J3),C(I,J1),C(I,K2),C(I,JU)
     1,C(I,K3)
  130 CONTINUE
  140 CONTINUE
C     PROVISION FOR A STOCK RESERVE PROGRAM OF 20 M.T. OF FG & 500 M.BU.
C     OF WHEAT
      IF(KNB.NE. 722) GO TO 141
      DO 142 I=3,NOBS
      C(I,291) =-10000.0* (ABS(C(I,150) + C(I,209) - 20.0) )
      C(I,292) =-10000.0* (ABS(C(I,151) + C(I,210) - 500.0) )
  142 CONTINUE
  141 CONTINUE
C     PENALTY FOR CORN PRICE GETTING OUT OF LINE WITH WHEAT.
      DO 143 I=3,NOBS
      IF(C(I,102).GT.(0.90909*C(I,26))) C(I,293) = -1000000.0   *
     1(ABS(C(I,102) -(0.90909 * C(I,26) )))
  143 CONTINUE
C     SUM THE PENALTY VALUES.
      SUM = 0.0
      DO 145 I=3,NOBS
      SUM    = C(I,271) +C(I,272) +C(I,273) +C(I,274) +C(I,275) +
```

```
     1C(I,276) +C(I,277) +C(I,278) +C(I,281) +C(I,282) +C(I,283) +
     2C(I,284) +C(I,285) +C(I,286) +C(I,287) +C(I,288) + SUM
     3 + C(I,291) + C(I,292) + C(I,293)
  145 CONTINUE
      F(IB) = SUM
      WRITE(6,2)  IB , F(IB)
      IF(IPRINT) 65,65,60
   60 CONTINUE
      DO 150 J=1,8
      JL=270+J
      JU=280+J
  150 WRITE(6,1) (C(I,JL),I=3,NOBS),(C(L,JU),L=3,NOBS)
C     ZERO OUT THE C MATRIX FOR THE NEXT TIME
   65 DO 80 J=1,220
      DO 75 I=3,NOBS
   75 C(I,J)=0.0
   80 CONTINUE
      IF (NCPOL.EQ.0) GO TO 81
      DO 79 J=1,NOPOL
      KOD=IDATA(1,J)
      ISTART=IDATA(2,J)
      IEND=IDATA(3,J)
      DO 76 I=ISTART,IEND
      L = (I - ISTART) + 1
   76 C(I,KOD)=CDATA(L,J)
   79 CONTINUE
   81 CONTINUE
C     RESTABLISH EXOG TO THE BASELINE VALUES AND USER SUPPLIED VALUES.
      DO 90 J=1,130
      DO 85 I=3,NOBS
   85 EXOG(I,J)=OLDEXO(I,J)
   90 CONTINUE
      EXG = EXOG(2,37)
      I=IB
      RETURN
      END
C***********************************************************************
      SUBROUTINE CONSTT
C***********************************************************************
C     SUB CONSTT CALLS THE RELEVANT SUBROUTINE FOR THE BOUNDARY CONSTRA-
C     INTS ON THE CONTROL VARIABLES, BASED ON THE FARM PROG. SIMULATED.
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
    1 FORMAT(' ',I4,10( 10F10.4,/,5X))
 1234 FORMAT(' ',2X, 'SUBROUTINE CONSTT')
      IF(NDEBUG.NE.0) WRITE(6,1234)
      IF(KNB  .EQ.  718) CALL CO718
      IF(KNB  .EQ.  719) CALL CO719
      IF(KNB  .EQ.  720) CALL CO720
      IF(KNB  .EQ.  721) CALL CO721
      IF(KNB  .EQ.  722) CALL CO722
      IF(KNB  .EQ.  723) CALL CO723
      IF(KNB  .EQ.  724) CALL CO724
      IF(NDEBUG.NE.0) WRITE(6,1) I,(X(I,L),L=1,M)
      RETURN
      END
C***********************************************************************
      SUBROUTINE CO718
C***********************************************************************
C     BOUNDARY CONSTRAINTS FOR CONTROL VARIABLES IN THE
C     ACREAGE SET-ASIDE PROGRAM ONLY
C 14  14   1   1   1   1   3   3   3   3   6   6
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
 1234 FORMAT(' ',2X, 'SUBROUTINE CO718')
      IF(NDEBUG.NE.0) WRITE(6,1234)
C           LOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      DO 10 L = 1,12
   10 G(L) = 0.0
C           UPPER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      DO 1 L=1,4
      LW=L+4
      LC=L+8
      H(L) = 0.35 * B(I,1)
      H(LW)= 0.35 * B(I,2)
      H(LC)= 0.28 * B(I,4)
    1 CONTINUE
      RETURN
      END
C***********************************************************************
      SUBROUTINE CO719
C***********************************************************************
C     BOUNDARY CONSTRAINTS FOR CONTROL VARIABLES IN THE
C     PRICE SUPPORT PROGRAM ONLY
C 14  14  55  55  55  55  54  54  54  54  56  56  56  56
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
 1234 FORMAT(' ',2X, 'SUBROUTINE CO719')
      IF(NDEBUG.NE.0) WRITE(6,1234)
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 1) = 2.0
      G( 2) = 2.0
      G( 3)= 2.0
      G( 4) = 2.0
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 5) = 1.75
      G( 6)= 1.75
      G( 7)= 1.75
      G( 8)= 1.75
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 9)= 0.37
      G(10)= 0.37
      G(11)= 0.37
      G(12)= 0.37
C     WHEAT UPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 1)= 3.00
      H( 2)= 3.16
      H( 3)= 3.34
      H( 4)= 3.52
C     CORN  UPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H(5)= 2.10
      H( 6)= 2.21
      H( 7)= 2.34
      H( 8)= 2.47
C     COTTONUPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 9)= 0.520
      H(10) = 0.548
      H(11)= 0.579
      H(12)= 0.610
      DO 1 L=1,4
      LC=L+4
      IF(X(I,LC).GT.(0.90909*X(I,L))) X(I,LC) = 0.90909 * X(I,L)
    1 CONTINUE
```

```
      RETURN
      END
C*************************************************************************
      SUBROUTINE CC720
C*************************************************************************
C     BOUNDARY CONSTRAINTS FOR CONTROL VARIABLES IN THE
C     INCOME SUPPORT (TARGET PRICE) PROGRAM.
C 14  14  52  52  52  52  51  51  51  51  53  53  53  53
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
 1234 FORMAT(' ',2X, 'SUBROUTINE CO720')
      IF(NDEBUG.NE.0) WRITE(6,1234)
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G( 1) = 3.00
      G( 2) = 3.16
      G( 3) = 3.34
      G( 4) = 3.52
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G( 5) = 2.10
      G( 6) = 2.21
      G( 7) = 2.34
      G( 8) = 2.47
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G( 9) = 0.52
      G(10) = .548
      G(11) = 0.579
      G(12) = .610
C     WHEAT UPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H( 1) = 4.00
      H( 2) = 4.21
      H( 3) = 4.45
      H( 4) = 4.69
C     CORN  UPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H( 5) = 3.16
      H( 6) = 3.26
      H( 7) = 3.45
      H( 8) = 3.64
C     COTTONUPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H( 9) = .75
      H(10) = .79
      H(11) = .835
      H(12) = .881
      DO 2 L=2,4
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    2 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10  * X(I,LW)
      DO 3 L=6,8
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    3 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10  * X(I,LW)
      DO 4 L=10,12
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    4 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10  * X(I,LW)
      DO 1 L=1,4
      LC=L+4
      IF(X(I,LC).GT.(0.90909 * X(I,L)) ) X(I,LC) = X(I,L) * 0.90909
    1 CONTINUE
      RETURN
      END
C*************************************************************************
      SUBROUTINE CC721
C*************************************************************************
C     BOUNDARY CONSTRAINTS FOR CONTROL VARIABLES IN THE
C     PRICE & INCOME SUPPORT PROGRAM.
      COMMON  /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXO(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
 1234 FORMAT(' ',2X, 'SUBROUTINE CC721')
      IF(NDEBUG.NE.0) WRITE(6,1234)
C    CONSTRAINTS FOR 721
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 1) = 2.0
      G( 2) = 2.0
      G( 3)= 2.0
      G( 4) = 2.0
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 5) = 1.75
      G( 6)= 1.75
      G( 7)= 1.75
      G( 8)= 1.75
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 9)= 0.37
      G(10)= 0.37
      G(11)= 0.37
      G(12)= 0.37
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G(13)= 3.00
      G(14)= 3.16
      G(15)= 3.34
      G(16)= 3.52
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G(17)= 2.10
      G(18)=2.21
      G(19)= 2.34
      G(20)=2.47
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G(21)= 0.520
      G(22)= 0.548
      G(23)= 0.579
      G(24)= 0.610
C     WHEAT UPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 1)= 3.00
      H( 2)= 3.16
      H( 3)= 3.34
      H( 4)= 3.52
C     CORN  UPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H(5)= 2.10
      H( 6)= 2.21
      H( 7)= 2.34
      H( 8)= 2.47
C     COTTONUPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 9)= 0.520
      H(10) = 0.548
      H(11)= 0.579
      H(12)= 0.610
C     WHEAT UPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H(13)= 4.00
      H(14)= 4.21
      H(15)= 4.45
      H(16)= 4.69
C     CORN  UPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H(17)= 3.16
      H(18)= 3.26
      H(19)= 3.45
      H(20)= 3.64
C     COTTONUPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
```

```
      H(21)= 0.750
      H(22)= 0.790
      H(23)= 0.835
      H(24)= 0.881
      DO 2 L= 2,4
      LW=L-1
      IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    2 CONTINUE
      DO 3 L= 6,8
      LW=L-1
      IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    3 CONTINUE
      DO 4 L= 10,12
      LW=L-1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
      IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
    4 CONTINUE
      DO 5 L= 14,16
      LW=L-1
      IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    5 CONTINUE
      DO 6 L= 18,20
      LW=L-1
      IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    6 CONTINUE
      DO 7 L= 22,24
      LW=L-1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
      IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
    7 CONTINUE
      DO 1 L=1,4
      LC=L+4
      L1=L+12
      L2=L+16
      IF( X(I,LC).GT.(0.90909*X(I,L)) ) X(I,LC) = 0.90909 * X(I,L)
      IF( X(I,L2).GT.(0.90909*X(I,L1))) X(I,L2) = 0.90909 * X(I,L1)
    1 CONTINUE
      RETURN
      END
C***********************************************************************
      SUBROUTINE CC722
C***********************************************************************
C     BOUNDARY CONSTRAINTS FOR CONTROL VARIABLES IN THE
C     ACREAGE SET-ASIDE & PRICE SUPPORT PROGRAM
      COMMON /CGOVS/  ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXC(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LO, J, I, IHOLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
 1234 FORMAT(' ',2X, 'SUBROUTINE CC722')
      IF(NDEBUG.NE.0) WRITE(6,1234)
C CONSTRAINTS FOR    722.
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 1)= 2.0
      G( 2)= 2.0
      G( 3)= 2.0
      G( 4)= 2.0
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 5)= 1.75
      G( 6)= 1.75
      G( 7)= 1.75
      G( 8)= 1.75
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 9)= 0.37
      G(10)= 0.37
      G(11)= 0.37
      G(12)= 0.37
      G(13)= 0.0
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      DO 10 L=14,24
   10 G(L) = 0.0
C     WHEAT UPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 1)= 3.00
      H( 2)= 3.16
      H( 3)= 3.34
      H( 4)= 3.52
C     CORN  UPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 5)= 2.10
      H( 6)= 2.21
      H( 7)= 2.34
      H( 8 )= 2.47
C     COTTONUPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 9)= 0.52
      H(10)= 0.548
      H(11)= 0.579
      H(12)= 0.610
C     CORN  UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      H(13)= 0.35 * 107.7
      H(14)= 0.35  * 107.7
      H(15)= 107.4 * 0.35
      H(16)= 107.2 * 0.35
C     WHEAT  UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      H(17)= 70.7  * 0.35
      H(18)= 71.1 * 0.35
      H(19)= 71.1 * 0.35
      H(20)= 71.1 * 0.35
C     COTTON UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      H(21)= 3.2
      H(22)= 3.3
      H(23)= 3.1
      H(24)= 3.2
      DO 2 L=2,4
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    2 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
      DO 3 L=6,8
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    3 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
      DO 4 L=10,12
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    4 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10   * X(I,LW)
      DO 1 L=1,4
      LC=L+4
      IF(X(I,LC).GT.(0.90909*X(I,L))) X(I,LC) = 0.90909 * X(I,L)
    1 CONTINUE
      RETURN
      END
C***********************************************************************
      SUBROUTINE CC723
C***********************************************************************
C     BOUNDARY CONSTRAINTS FOR CONTROL VARIABLES IN THE
C     ACREAGE SET-ASIDE, PRICE & INCOME SUPPORT PROGRAM
      COMMON  /CGOVS/   ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1EXOG(14,180), OLDEXC(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
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     2IS, LC, J, I, IHCLD1, IHOLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
 1234 FORMAT(' ',2X, 'SUBROUTINE CC723')
      IF(NDEBUG.NE.0) WRITE(6,1234)
C     CONSTRAINTS FOR 723
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 1)= 2.00
      G( 2)= 2.00
      G( 3)= 2.00
      G( 4)= 2.00
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 5)= 1.75
      G( 6)= 1.75
      G( 7)= 1.75
      G( 8)=  1.75
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      G( 9)= 0.37
      G(10)= 0.37
      G(11)= 0.37
      G(12)= 0.37
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      DO 10 L=13,24
   10 G(L) = 0.0
C     WHEAT UPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 1)= 3.00
      H( 2)= 3.16
      H( 3)= 3.34
      H( 4)= 3.52
C     CORN  UPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 5)= 2.10
      H( 6)= 2.21
      H( 7)= 2.34
      H( 8)= 2.47
C     COTTONUPPER BOUNDARY CONSTRAINTS, TABLE 1, FOR LOAN RATES
      H( 9)= 0.52
      H(10)= 0.54
      H(11)= 0.579
      H(12)= 0.610
C     CORN   UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      H(13)= 0.35 * 107.7
      H(14)= 0.35  * 107.7
      H(15)= 107.4 * 0.35
      H(16)= 107.2 * 0.35
C     WHEAT  UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      H(17)= 70.7  * 0.35
      H(18)= 71.1 * 0.35
      H(19)= 71.1 * 0.35
      H(20)= 71.1 * 0.35
C     COTTON UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      H(21)= 3.2
      H(22)= 3.3
      H(23)= 3.1
      H(24)= 3.2
      DO 2 L=2,4
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    2 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10  * X(I,LW)
      DO 3 L=6,8
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    3 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10  * X(I,LW)
      DO 4 L=10,12
      LW = L - 1
      IF(X(I,L).LT.X(I,LW)) X(I,L) = X(I,LW)
    4 IF(X(I,L).GT.(1.10 * X(I,LW))) X(I,L) = 1.10  * X(I,LW)
      DO 1 L=1,4
      LC=L+4
      IF(X(I,LC).GT.(0.90909*X(I,L))) X(I,LC) = 0.90909 * X(I,L)
    1 CONTINUE
      RETURN
      END
C*****************************************************************************
      SUBROUTINE CC724
C*****************************************************************************
C     BOUNDARY CONSTRAINTS FOR CONTROL VARIABLES IN THE
C     ACREAGE SET-ASIDE & INCOME SUPPORT PROGRAM
C CONSTRAINTS 724.
      COMMON  /CGOVS/   ADJ(65), CONST(110), AY(16), C(14,300),B(14,300),
     1FXOG(14,180), OLDEXG(14,180), E(200), EXG, IFLAG, JJ, IP, IG, IE,
     2IS, LC, J, I, IHOLD1, IHCLD2, AHOLD1, AHOLD2, AHOLD3, AHOLD4
      COMMON  /BMAIN3/  X(60,99) ,N,M,K,IEV1,IEV2,  K1,F(60),G(99),H(99)
     1,XC(60),NDEBUG  ,KNB,NB2,NB3,NB1
 1234 FORMAT(' ',2X, 'SUBROUTINE CC724')
      IF(NDEBUG.NE.0) WRITE(6,1234)
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G( 1) = 3.00
      G( 2) = 3.16
      G( 3) = 3.34
      G( 4) = 3.52
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G( 5) = 2.10
      G( 6) = 2.21
      G( 7) = 2.34
      G( 8) = 2.47
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G( 9) = 0.52
      G(10) = .548
      G(11) = 0.579
      G(12) = .610
C     WHEAT LOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
C     CORN  LOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
C     COTTONLOWER BOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      DO 20 II=13,24
   20 G(II) = 0.0
C           LOWER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      G(25) = 3.00
      G(26) = 2.10
      G(27) = 0.52
C     WHEAT UPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H( 1) = 4.00
      H( 2) = 4.21
      H( 3) = 4.45
      H( 4) = 4.69
C     CORN  UPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H( 5) = 3.16
      H( 6) = 3.26
      H( 7) = 3.45
      H( 8) = 3.64
C     COTTONUPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H( 9) = .75
      H(10) = .79
      H(11) = .835
      H(12) = .881
C     CORN   UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      H(13)= 0.35 * 107.7
      H(14)= 0.35  * 107.7
      H(15)= 107.4 * 0.35
      H(16)= 107.2 * 0.35
C     WHEAT  UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
```

```
      H(17)= 70.7  * 0.35
      H(18)= 71.1  * 0.35
      H(19)= 71.1  * 0.35
      H(20)= 71.1  * 0.35
C     COTTON UPPERBOUNDARY CONSTRAINTS, TABLE 3, FOR SET-ASIDE
      H(21)= 3.2
      H(22)= 3.3
      H(23)= 3.1
      H(24)= 3.2
C             UPPER BOUNDARY CONSTRAINTS, TABLE 2, FOR TARGET PRICES
      H(25) = 4.00
      H(26) = 3.16
      H(27) = 0.75
      DO 1 L=1,4
      LC=L+4
      IF(X(I,LC).GT.(0.90909*X(I,L)) ) X(I,LC) = 0.90909 * X(I,L)
    1 CONTINUE
      RETURN
      END
C***********************************************************************
      FUNCTION RANG(NARG)
C***********************************************************************
C  GENERATES PSEUDO-RANDOM NUMBERS, UNIFORMLY DISTRIBUTED ON (0,1).
C  THIS VERSION IS FOR THE IBM 360.
      EQUIVALENCE (RAN,JRAN)
      DIMENSION N(128)
      DATA NFIRST/1/,K/7654321/,L/3141593/,M/2718281837/
      DATA MK/231525/,ML/282629/,MM/253125/
      IF(NARG)20,10,20
   10 IF(NFIRST)30,60,30
   20 KLM=IABS(2*NARG+1)
      K=KLM
      L=KLM
      M=KLM
      NARG=0
   30 NFIRST=0
      NDIV=16777216
      RDIV=32768.*65536.
      DO 50 J=1,128
      K=K*MK
   50 N(J)=K
   60 L=L*ML
      J=1+IABS(L)/NDIV
      M=M*MM
      NR=IABS(N(J)+L+M)
      RAN=FLOAT(NR)/RDIV
```

```
C/////  BOXFILE IS A FORTRAN PROGRAM TO PUT ON DISK THE FILE NOS. THAT
C/////  MAP THE EXOG FILES IN POLYSIM INTO THE X, G, H, & XC FILES IN
C/////  BOX'S COMPLEX PROCEDURE.
C/////  CODE THE DATA CARDS AS: 3 CARDS PER FARM PROGRAM, USING 20I4
C/////  FORMAT,  THE ORDER OF THE 7 SETS IS THE SAME AS THE ORDER OF
C/////  THE ''C0718-C0724'' SUBROUTINES.
C/////    EXAMPLE:  CODE CC.  1-4     TWO PLUS THE NO. OF CONTROLS
C/////    EXAMPLE:  CODE CC.  5-8     TWO PLUS THE NO. OF CONTROLS
C/////    EXAMPLE:  CODE CC.  9-12    EXOG FILE NO. FOR FIRST  CONTROL
C/////    EXAMPLE:  CODE CC. 13-16    EXOG FILE NO. FOR SECOND CONTROL
C/////    EXAMPLE:  CODE CC. 17-20    EXOG FILE NO. FOR THIRD  CONTROL
C/////    EXAMPLE:  CODE CC. 21-24    EXOG FILE NO. FOR FOURTH CONTROL
C/////    EXAMPLE:  CODE CC. 25-28    EXOG FILE NO. FOR FIFTH  CONTROL
C/////    EXAMPLE:  CODE CC. 29-32    EXOG FILE NO. FOR SIXTH  CONTROL
C/////    EXAMPLE:  CODE CC. 33-80    IN THE SAME MANNER , CONTINUE ON
C/////    EXAMPLE:                    A SECOND & THIRD CARD TO COMPLETE
C/////    EXAMPLE:                    THE 3 CARD SET. USE 3 CARDS EVEN
C/////    EXAMPLE:                    IF THE LAST 2 ARE BLANK.
C/////    WRITTEN BY JWR 8/77.
      DIMENSION NFILE(90),NF(90),NB(90,10)
      DEFINE FILE 10(999,90,U,JNEXT)
    1 FORMAT(20I4)
    2 FORMAT(' ',31I4)
    3 FORMAT(' ',I4,10X,7(I4,3X))
      DO 100 I=1,90
      NFILE(I) = 0.0
  100 NF(I) = 0.0
      DO 200 L=1,7
      READ(5,1) (NFILE(I),I=1,60)
      WRITE(6,2) (NFILE(I),I=1,60),L
      KF=L+ 717
      WRITE(10' KF) (NFILE(I),I=1,90)
      DO 150 K=1,90
  150 NFILE(K)=NF(K)
  200 CONTINUE
      DO 300 L=1,7
      KF=L + 717
  300 READ(10' KF) (NB(J,L),J=1,90)
      DO 400 L=1,60
  400 WRITE(6,3) L,(NB(L,J),J=1,7)
       STOP
      END
  14  14   1   1   1   1   3   3   3   3   6   6   6   6
  00
  00
  14  14  55  55  55  55  54  54  54  54  56  56  56  56
  00
  00
  14  14  52  52  52  52  51  51  51  51  53  53  53  53
  00
  00
  26  26  55  55  55  55  54  54  54  54  56  56  56  56  52  52  52  52  51  51
  51  51  53  53  53  53
  00
  26  26  55  55  55  55  54  54  54  54  56  56  56  56   1   1   1   1   3   3
   3   3   6   6   6   6
  00
  29  29  55  55  55  55  54  54  54  54  56  56  56  56  01  01  01  01  03  03
  03  03  06  06  06  06
  00
  26  26   1   1   1   1   3   3   3   3   6   6   6   6  52  52  52  52  51  51
  51  51  53  53  53  53
  00
```

APPENDIX B

DESCRIPTION AND LISTING OF DATA CARDS FOR THE CONTROL THEORY OPTION IN POLYSIM

The POLYSIM User's Manual describes the data cards required to run the model, as well as, the coding instructions for the Core Data Cards (Name Card, Simulation Card, and Farm Program Card) and the Optional Data Cards (Richardson and Ray, 1974a). The additional data cards required to use the Control Theory Option in POLYSIM are described in this Appendix.

Changes in POLYSIM Data Cards

The Control Theory Option is activated by coding a '1' in card column 77 of the Simulation Card. Other than the '1' in column 77, the coding instructions for the Simulation Card are the same as those presented in the POLYSIM User's Manual. It should be noted that the policy programs coded on the Farm Program Card determine the control variables (farm policy variables) the model uses to maximize the performance measure. If an acreage set-aside program is selected, the set-aside levels for feed grains, wheat and cotton are the control variables. Similarly, when price and income support programs are used, separately or together, the control variables are respectively, loan rates and target prices for corn, wheat and cotton.

Performance Measure Cards

To generalize the Control Theory Option, provisions are available that allow the user to provide the upper and lower boundaries of the output variables used in the performance measure and their respective parameter weights. The values for the performance measure are provided by the user on the Performance Measure Cards, a new set of Optional Data Cards created for the Control Theory Option.

The performance measure described in the text is:

If lower bound level is violated -

$$JL_{ij} = H_{ij} \left| Y_{ij} - LB_{ij} \right|$$

If upper bound level is violated -

$$JU_{ij} = I_{ij} \left| Y_{ij} - UB_{ij} \right|$$

$$\text{Maximize:} \quad J = \sum_{j=1}^{4} \left[\sum_{i=1}^{n} (JL_{ij} + JU_{ij}) \right]$$

where H_{ij} is the weight for output variable Y_i violating a lower boundary level LB_i in period j; I_{ij} is the weight for output variable Y_i violating an upper boundary level UB_i in period j. Values for variables LB_{ij} and UB_{ij} and parameter weights H_{ij} and I_{ij} used in this study are presented in Table IV.

A list of the output variables in POLYSIM associated with variables LB_{ij} and UB_{ij}, in this study, are presented in Table XX. Also, Table XX includes a list of the parameter weights, H_{ij} and I_{ij}, in the performance measure. Each data series (LB_{ij}, UB_{ij}, H_{ij}, I_{ij}) is entered on a separate Performance Measure Card, using the variable code in Table XX to identify the particular series being provided. For example, the boundary level for feed grain ending year carryover is identified by code number 235, and the lower boundary parameter weight for the variable is identified by code number 261 (Table XX).

Coding instructions for the Performance Measure Cards are presented below:

TABLE XX

VARIABLE CODES FOR OUTPUT VARIABLES, BOUNDARY LEVELS, AND PARAMETER WEIGHTS USED IN POLYSIM FOR THE PERFORMANCE MEASURE

Variable Codes	Output Variables	Abbreviated Variable Name
	Output Variables in Performance Measure (J)	
B 93	Realized net farm income m. $	Y_{1j}
B 212	Net income to livestock producers m. $	Y_{2j}
B 100	Total U. S. consumer expenditure for food m. $	Y_{3j}
B 96	Total government payments to farmers m. $	Y_{4j}
B 202	Total Commodity Credit Corporation (CCC) storage and interest costs	Y_{5j}
B 41	Feed grain ending year carryover m. t.	Y_{6j}
B 42	Wheat ending year carryover m. bu.	Y_{7j}
B 44	Cotton ending year carryover m. net bales	Y_{8j}
	Lower and Upper Boundary Levels for Output Variables	
B 225	Lower boundary level of realized net farm income m. $	LB_{1j}
B 226	Upper boundary level of realized net farm income m. $	UB_{1j}
B 227	Lower boundary level of net income to livestock producers m. $	LB_{2j}
B 228	Upper boundary level of net income to livestock producers m. $	UB_{2j}
B 229	Lower boundary level of total U. S. consumer expenditure for food m. $	LB_{3j}
B 230	Upper boundary level of total U. S. consumer expenditure for food m. $	UB_{3j}
B 231	Lower boundary level of total government payments to farmers m. t.	LB_{4j}

TABLE XX (CONTINUED)

Variable Codes	Output Variables	Abbrevaited Variable Name
B 232	Upper boundary level of total government payments to farmers m. t.	UB_{4j}
B 233	Lower boundary level of total CCC storage and interest costs m. $	LB_{5j}
B 234	Upper boundary level of total CCC storage and interest costs m. $	UB_{5j}
B 235	Lower boundary level of feed grain ending year carryover m. t.	LB_{6j}
B 236	Upper boundary level of feed grain ending year carryover m. t.	UB_{6j}
B 237	Lower boundary level of wheat ending year carryover m. t.	LB_{7j}
B 238	Upper boundary level of wheat ending year carryover m. t.	UB_{7j}
B 239	Lower boundary level of cotton ending year carryover m. net bales	LB_{8j}
B 240	Upper boundary level of cotton ending year carryover m. net bales	UB_{8j}
	Lower and Upper Boundary Parameter Weights for Output Variables	
B 251	Lower boundary parameter weight for realized net farm income	H_{1j}
B 252	Upper boundary parameter weight for realized net farm income	I_{1j}
B 253	Lower boundary parameter weight for net income to livestock producers	H_{2j}
B 254	Upper boundary parameter weight for net income to livestock producers	I_{2j}
B 255	Lower boundary parameter weight for total U. S. consumer expenditure for food	H_{3j}
B 256	Upper boundary parameter weight for total U. S. consumer expenditure for food	I_{3j}
B 257	Lower boundary parameter weight for total government payments to farmers	H_{4j}
B 258	Upper boundary parameter weight for total government payments to farmers	I_{4j}

TABLE XX (CONTINUED)

Variable Codes	Output Variables	Abbreviated Variable Name
B 259	Lower boundary parameter weight for total CCC storage and interest costs	H_{5j}
B 260	Upper boundary parameter weight for total CCC storage and interest costs	I_{5j}
B 261	Lower boundary parameter weight for feed grain ending year carryover	H_{6j}
B 262	Upper boundary parameter weight for feed grain ending year carryover	I_{6j}
B 263	Lower boundary parameter weight for wheat ending year carryover	H_{7j}
B 264	Upper boundary parameter weight for wheat ending year carryover	I_{7j}
B 265	Lower boundary parameter weight for cotton ending year carryover	H_{8j}
B 266	Upper boundary parameter weight for cotton ending year carryover	I_{8j}

Card Column	
1	Enter a '6'.
2-20	A user specified name for the data series being provided, for example: 'LB GOVT PAYMENTS'.
21-23	The variable code in Table XX associated with the data series being provided, for example: enter '231' for the lower boundary level of government payments.
24-25	The last two digits of the first calendar year to be simulated, i.e., '78' if the first year simulated is 1978.
26-29	Blank.
30	The number of years of data being provided '4', since the study period is four years.
31-40	The value of the data series for the first year to be simulated. Punch all values with a decimal point (say, 2.0), if the value is negative enter it as a negative (say, -1.5).
41-50	The value of the data series for the second year to be simulated.
51-60	The value of the data series for the third year to be simulated.
61-70	The value of the data series for the fourth year to be simulated.
71-80	Blank.

The user may use as many Performance Measure Cards as necessary to enter all of the boundary levels and parameter weights for the performance measure. (Upper and lower boundary levels for the farm income variables (225-228) are ignored by the model in its current form; but, are provided in Table XX for completeness.) Following the last Optional Data Card (the last Performance Measure Card) the user must provide the data cards for the Control Theory Option.

Data Cards for the Control Theory Option

Data cards for the Control Theory Option are separated from the POLYSIM data cards by one blank card. The first data card for the Control Theory Option is an I-O Card. The I-O Card provides a means for the user to indicate the type of input to be provided and the type of printed output desired from the model. The second card or Parameter Card is provided for the user to input parameters necessary for the optimization routine. The Parameter Card is the last data card unless the user selects the input option of providing the starting values for each of the m control variables. In such a case, m+1 (or k) Starting Values Cards follow the Parameter Card.

I-O Card

The I-O Card is the first data card for the Control Theory Option; it provides four options for entering the initial values for the control variables (policy variables) and three options for printing the output. Code the I-O Card as follows:

Card Column	
1	Punch a '7'.
2-10	Punch 'II-O CARD'.
11-20	An odd, six-digit number, to be used as a random number generator seed (punched with decimal point) as '999991.0'.
21-24	Code '00000' if a minimum amount of output is desired until the maximum value of the performance measure is found. Code '0001' to print the value of the control variables, and the performance measure on each iteration.
25-28	Code '0001' to use the de-bug option for locating problems in the COMPLEX subroutines.

29-32	The option to indicate the source of the k initial values for the m control variables. A '0000' indicates the program will use the baseline values for one point, and select values for k-1 points at random. A '0001' indicates the user will provide data cards for the initial values of all control variables. A '0002' indicates that the initial values for all k points are to be selected at random. A '0003' indicates that initial values for all k points were stored on a direct access disk (unit 16) in a previous run and are to be used for this run.
33-80	Blank.

Parameter Card

The computer program used in this study to execute Box's Complex Procedure requires values for five parameters. These parameters are provided by the user on the Parameter Card. (Integers must be right justified.)

Card Column	
1	Punch an '8'.
2-10	Punch 'PARAMETER'.
11-20	The reflection factor ALPHA, Box (1965) suggests using '1.3'.
21-30	The convergence parameter BETA, as '0.50'.
31-40	The within bounds accuracy for the constraints, DELTA, as '0.001'.
41-44	The number of iterations to continue searching after finding an optimal, GAMMA, as '0005'.
45-48	The maximum number of iterations the search program can go through in trying to locate the maximum of the performance measure, as '0400'.
49-80	Blank.

When a control path (a coordinate on the surface of the performance measure) is rejected the new values for the control variables are moved

ALPHA units closer to the centroid. By using a value greater than one (1.3) we are assured of searching both sides of the centroid for the optimal control path. The Complex Procedure assumes convergence when the value of the performance measure for the k points on the surface is within BETA units for GAMMA iterations. When control values are selected that lie outside the boundary constraints, the control value is moved inside the violated boundary by DELTA units. More detailed descriptions of the parameters are available in Kuester and Mize (1973).

Starting Value Cards

The Starting Value Cards are used when the user chooses to provide the m+1 (or k) starting values or control paths for the m control variables (option '0001' in card columns 28-32 of the I-O Cards). The starting values are stored in a k by m matrix, X. Each Starting Value Card provides values for m control variables, so k different Starting Value Cards must be provided. The order of the control variables on the Starting Value Cards depends upon the farm program being simulated, since each program has a different set of controls. The order of the control variables is indicated in Table XIX for each of the seven farm programs available in the Control Theory Option. For example, the storage locations in the X matrix, for an income support program, are: columns 1-4 for wheat target prices, columns 5-8 for corn target prices, and columns 9-12 for cotton target prices (Table XIX). To input data for the X matrix, the position of variables on the Starting Value Cards must follow the order of control variables in Table XIX.

The initial values for the first eight control variables in any of the seven farm programs are coded as:

Card Column	
1-10	Value for X(1,1), punched with decimal point.
11-20	Value for X(1,2), punched with decimal point.
21-30	Value for X(1,3), punched with decimal point.
31-40	Value for X(1,4), punched with decimal point.
41-50	Value for X(1,5), punched with decimal point.
51-60	Value for X(1,6), punched with decimal point.
61-70	Value for X(1,7), punched with decimal point.
71-80	Value for X(1,8), punched with decimal point.

This same format is used for the next set of eight control variables if necessary for the program being sinulated or X(1,9) through X(1,16) in Table XIX. If more than 16 control variables are being used, continue on a third and fourth card, until reaching control variable X(1,M) in Table XIX. Then repeat the process for the second point or X(2,i), i = 1, 2, ..., m. The process is complete after coding k sets of the Starting Value Cards.

As new values for the control variables are calculated, during the solution of the Complex Procedure, they are stored in the X matrix. The X matrix is stored on a direct access disk (unit 16) every tenth iteration, so if the programs stops prematurely the calculations can be resumed at the last solution set stored on disk. Calculations can be resumed by re-submitting the program with option '0003' specified in card column 28-32 of the I-O Card. The process of re-submitting the program can be repeated as many times as necessary to get the program to a maximum value for the performance measure.

To reiterate, the cards needed to activate the Control Theory Option for POLYSIM, in the order in which they must appear, are:

One Blank Card,

The Name Card,

The Simulation Card (with '1' in column 77),

The Farm Program Card,

Optional Data Cards:

Elasticity Cards,

Policy Data Cards,

Predetermined Data Cards,

Performance Measure Cards,

One Blank Card,

The I-O Card,

The Parameter Card,

The k Starting Value Cards (these are optional).

A listing of the data cards used to evaluate farm program No. 4 are presented in this Appendix to aid the user in understanding the different cards described above.

```
0
1    FARM PROGRAM NO.4, PRICE & INCOME SUPPORT WITH SET-ASIDE, HIGH EXPORTS 78
2                        78C04                                                  1
3 FFGM                    1C01001
5 CCRN TARGET          05178      4 2.10       2.21       2.34       2.47
5 WHET TARGET          05278      4 3.00       3.16       3.34       3.52
5 CCTT TARGET          05378      4 .52         .548      .579       .610
5 FG PAYMENT / AC      07578      4 53.43     54.51      55.59      56.71
5 WHTPAYMENT / AC      C7678      4 32.23      32.87     33.53      34.20
5 CCTPAYMENT / AC      07778      4 78.26      79.83     81.43       83.06
5 FC PART RATE         08678      4  .65        .65        .65         .65
5 WHTPART RATE         08778      4  .8        .8         .8         .8
5 CCTPART RATE         08878      4  .8        .8         .8         .8
5 FC SLIPPAGE          C8278      4   .4      .4          .4        .4
5 WHTSLIPPAGE          08378      4   .4      .4          .4        .4
5 CCTSLIPPAGE          08578      4   .4      .4          .4        .4
5 FG CCC CCSTS         C0878      3 2.14      7.14       .075
5 WHT CCC COSTS        01078      3  .06       .22        .075
5 CCT CCC COSTS        01478      3  1.44       5.40        .075
6 FC EXPORTS           03778      1  93.82
6 WH EXPCRTS           03878      1  1617.33
6 CC EXPCRTS           04078      1  7.05
6 LB FARM INCOME       22578      4  0.0       0.C         0.0        0.0
6 UB FARM INCOME       22678      4  0.0       0.0         0.0        0.0
6 LB LVSK INCOME       22778      4  0.0       0.0         0.0        0.0
6 UB LVSK INCOME       22878      4  0.0       0.0         0.0        0.0
6 LB FCCD COSTS        22978      4 188300.  192500.   202600.   211400.
6 UB FOOD COSTS        23C78      4 190183.  194425.   204626.   213514.
6 LB GCVT PAYMENTS     23178      4 850.       850.      850.       850.
6 UB GCVT PAYMENTS     23278      4 3700.     3700.      3700.      3700.
6 LB CCC COSTS         23378      4 0.0        0.0       0.0         0.0
6 UB CCC COSTS         23478      4  600.      600.      600.       600.
6 LB FG STCCKS         23578      4 30.        30.       30.        30.
6 UB FG STOCKS         23678      4 60.         60.        60.         60.
6 LB WHT STOCKS        23778      4 600.       600.      600.       600.
6 UB WHT STOCKS        23878      4 1200.       1200.     1200.       1200.
6 LB CCT STOCKS        23978      4  2.        2.        2.         2.
6 UB CCT STOCKS        24078      4  4.        4.       4.          4.
6 H FARM INCCME        25178      4  1.         1.         1.         1.
6 I FARM INCOME        25278      4  1.         1.         1.         1.
6 H LVSK INCCME        25378      4 1.          1.        1.         1.
6 I LVSK INCCME        25478      4 1.          1.        1.         1.
6 H FCCD CCSTS LOW     25578      4 2.        2.          2.         2.
6 I FCCD CCSTS LOW     25678      4 -2.0       -2.0        -2.0       -2.0
6 H GGVT PAYMT LOW     25778      4 0.0        0.0       0.0         0.0
6 I GCVT PAYMT LOW     25878      4 -1.5       -1.5        -1.5       -1.5
6 H CCC COSTS LOW      25978      4 0.0        0.0       0.0         0.0
6 I CCC COSTS LOW      26078      4 -1.5        -1.5       -1.5       -1.5
6 H FG STOCKS          26178      4 -104.        -104.      -104.   -104.
6 I FG STOCKS          26278      4 -82.5      -82.5     -82.5     -82.5
6 H WHT STOCKS         26378      4 -3.4       -3.4        -3.4       -3.4
6 I WHT STCCKS         26478      4 -2.8        -2.8        -2.8        -2.8
6 H CCT STOCKS         26578      4 -284.8      -284.8      -284.8    -284.8
6 I CCT STOCKS         26678      4 -268.6      -268.6    -268.6       -268.6
0
7 I-C CARD 999997.C          0    0
8PARAMETER 1.3        10.C        0.001        50650
```

VITA 2

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