A SIMULATION ANALYSIS OF THE ECONOMIC STRUCTURE OF U. S. AGRICULTURE

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CHAPTER I

INTRODUCTION

Problems of Agriculture

The concept of "the farm problem" has received abundant attention. In view of the range of definitions encountered in the literature, and in order to have a starting point for this investigation, a definition of this farm problem is required. Farm "problems" are many, including the instability of farm prices and incomes, rural poverty, problems of specific commodities, low absolute incomes, and low relative incomes. Professor Shepherd has presented the situation concisely:

> It is necessary to distinguish just what the agricultural price and income problem is--whether there really is a problem, or only appears to be; whether it is a price problem, or an income problem; whether it is a problem of income stability, or level, of production overcapacity; whether it affects all farmers, or only small farmers, or large commercial farms, or livestock or crop farmers, or some other group--and then to determine the causes, so as to be in the best position to appraise remedial action. [1]

The income and production aspects of farm problems are examined in greater detail in the following section to further delineate the "farm problem" to be considered.

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[1] Geoffrey S. Shepherd, Farm Policy: New Directions (Ames, 1964), p. 5.

Indications of Disequilibrium

The income problem may be discussed in terms of the incomes of farm and nonfarm workers. Annual farm income per worker[2] increased from an average of $338 in the 1910-14 period to $2,375 in 1963 (current dollars).[3] During the same period the average annual wage per employed factory worker increased from $547 to $5,168.[4] In terms of relative incomes the ratio of farm to nonfarm worker incomes decreased from .62 in 1910-14 to .46 in 1963.

During the 1910-63 period, total gross farm income increased from $7.7 billion (1910-14 average) to a $40.5 billion (1963) in current dollars, but production expenses increased more rapidly, so that total net income as a percentage of total gross income declined from 51.0 to 30.8.[5]

The index of farm output measures the volume of farm production available for eventual human use.[6] Relative to a 1957-59 base, output has increased from an index of 51 in 1910 to 68 in 1939, and to 112 in 1963.[7] The increase of 44 in the index over the last 24 years compared

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[2] Realized net income from farming (including government payments plus total farm wages) divided by the average number of persons engaged in agriculture during the year (including farm operators and other family workers as well as hired workers).

[3] U. S. Department of Agriculture, Farm Income Situation, ERS (Washington, 1964), p. 43.

[4] Ibid., p. 43.

[5] Ibid., p. 37.

[6] U. S. Department of Agriculture, Changes in Farm Production and Efficiency, ERS, Statistical Bulletin No. 233 (Washington, 1964), p. 6.

[7] Ibid., pp. 7-8.

with the increase of 17 in the 29-year earlier period indicates the rapid increases in output brought about by technological improvements during the past two and one-half decades.

In view of this tremendous increase in output, coupled with a declining farm population, why have incomes not increased? The answer lies partly in rising prices farmers pay for production items, but primarily in the response of prices received by farmers to increased output. This response, the measure of which is called the price elasticity of demand, is such that an increase in output can only be sold at prices reduced proportionally more than output increases.

Based on a price elasticity of demand for farm products of -.25, a 1.0 percent increase in the quantity of agricultural commodities placed on the market will occasion a 4.0 percent drop in price.

The commercial farm problem has been defined as an excess of farm production capacity. The magnitude of this excess capacity has been estimated for the years 1955-62.[8] By employing the idea of "socially acceptable prices" (defined as national average farm commodity prices resulting from government stabilization of prices through the Commodity Credit Corporation, acreage removals, and export programs) the divergence between "unregulated production"[9] and "commercial

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[8] Fred H. Tyner and Luther G. Tweeten, "Excess Capacity in U. S. Agriculture", Agricultural Economics Research, XVI (Washington, 1964), p. 28.

[9] Unregulated production is defined as the quantity of output which would have entered the commercial market in the absence of government diversions through Commodity Credit Corporation, land withdrawal programs, and subsidized exports.

utilization"[10] provides the specification of an "adjustment gap." The adjustment gap (ratio of diversions to probable output) in percentage terms was estimated as follows:

Year	Adjustment Gap
1955-56	6.4
1956-57	5.3
1957-58	9.1
1958-59	11.2
1959-60	9.1
1960-61	7.1
1961-62	7.4

The most important implication of these estimates is that prices would have been depressed by from about 20 to 40 percent if these quantities had not been diverted, and would have strongly accented the income problem.

Excess aggregate production implies an over-commitment of resources to agriculture. This raises questions of "Which particular resources are in over-supply?" "How might an economic equilibrium be achieved?" and "What would be the effects of resource reallocations on the resources themselves, farming communities, and the nonfarm sector?" What has been the impact of changes in nonfarm variables on farm adjustments? It will be the task of this study to estimate the productivity of various resources used in farming, develop hypotheses relating to the effects of changes in selected variables on farm output and incomes, and estimate the extent of farm-nonfarm interrelations through selected resource markets. Explicit objectives will be given in the final section of this chapter.

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[10] Commercial utilization is defined as the quantity of output selling at "market prices" in the domestic sector plus estimates of exports that would have occurred in the absence of subsidies.

Why Problems Exist and Persist

The problems of commercial agriculture have arisen because the American farmer has been quick to take advantage of innovations such as hybrid seeds, improved livestock breeds, efficient machinery, chemical weed- and pest-control agents, and high-analysis fertilizers, which the nonfarm economy has provided. The rapid adoption of new production techniques has allowed output per worker to expand such that fewer persons are required on farms.

For resource use to remain in equilibrium (or not to diverge further from equilibrium) given these technological advances, a reallocation of resources is required. Given the relative constancy of agricultural output demanded, a reduction in certain resources is indicated. As an example of problems this poses, however, land can either be idled or else gradually transferred out of agricultural use to urban use for recreation, housing, shopping areas, industrial parks, airports, and roads.

Current demand for new farm operators is sufficient to provide employment for only a small fraction of today's farm youth as replacements for retiring farm operators. This potential excess of manpower plus the current excess sums to a figure that creates tremendous problems of finding employment in the urbanized sector. A general approach to the immobility of resources in agriculture discussed below indicates more clearly reasons why reallocation does not occur rapidly.

An equilibrium use of resources in the economy is defined as that use which equates returns to any given resource between its alternative employments. Theoretically, a resource will be transferred to higher-paying uses until equilibrium is reached if certain conditions of mobility are met. Since disparate returns exist for certain resources between farm and nonfarm uses, these conditions are obviously not met. The fact of the matter is that the nature of many farm resources inhibits their use in nonfarm employment. Transformation of these resources into other capital forms is hindered by low salvage values. This "resource fixity" concept is presented by Johnson[11], Hathaway[12], and others so it is not necessary to elaborate it here.

Besides the purely economic criteria indicated in the preceeding paragraphs, certain non-economic phenomena provide strong barriers to timely reallocation of resources. Some of these are goals and values of farm and nonfarm people and the declining political power of the rural constituency. Goals and values are identified as the major problems in farm policy by Heady and Burchinal.[13] Regarding the "farm problems" they say that: "The problem continues not because economists lack general understanding of its causes or alternatives which could alleviate it, but because public agreement is generally lacking on the appropriate means and, to an extent, on the proper objectives of farm policy."[14] The long-adhered to "agricultural fundamentalism" concept which Paarlberg[15]

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[11] Glenn L. Johnson, "Supply Function - Some Facts and Notions," Agricultural Adjustment Problems in a Growing Economy (Ames, 1958), pp. 78ff.

[12] Dale E. Hathaway, Government and Agriculture (New York, 1963), pp. 110ff.

[13] Earl O. Heady and Lee G. Burchinal, "The Concern With Goals and Values in Agriculture," Goals and Values in Agricultural Policy, Iowa State University Center for Agricultural and Economic Adjustment (Ames, 1961), Chapter 1.

[14] Ibid., p. 1.

[15] Don Paarlberg, American Farm Policy (New York, 1964), Chapter 1.

details in his Agricultural Creed apparently remains a strong deterrent to sound policy formulation and implementation.

Attempts to Solve These Problems

In order to form the setting for evalution of alternative policies, let us consider briefly the approaches taken in the recent past. Programs have embodied such measures as raising or stabilizing prices farmers receive directly, controlling prices and quantities indirectly through marketing agreements and orders, providing increased credit, attempts to expand the demand for farm products, direct payments to producers, and production adjustments through administrative controls. The lack of a consistent pattern is pointed out in the following statement:

> Since about 1920, therefore, the United States has had no clearly defined agricultural policy. Because of this, agricultural programs and activities for the past two and a half decades have lacked an over-all guiding purpose and have been undertaken in haphazard fashion one at a time to meet each specific agricultural "problem" as it arose.[16]

Since the 1910-14 period was viewed as a "fair" period for agriculture, we can use it as a starting point for a brief review of U. S. agricultural problems and policies. With the expanding urban sector farmers could leave agriculture in substantial numbers. Inflation engendered by World War I placed a heavy debt and tax burden on agriculture. Continued high output coupled with reduced demand after the war caused prices received by farmers to drop from an index of 228 (1909-14 = 100) in 1919 to 128 in 1921.

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[16] U. S. Congress, 80th Congress, 1st Session, Long-Range Agricultural Policy, Preliminary Report of the Committee on Agriculture of the House of Representatives (Washington, 1947), p. 13.

Demand for action programs took the form of commodity cooperatives and "big business" tactics. When these efforts met with limited success, the idea of government programs gained acceptance. Though many farmers rejected the idea that

> . . . a monopoly type approach was either feasible or desirable, . . ., such techniques were to become prominent and widely favored, in the McNary-Haugen plan so vigorously pushed in the last half of the 1920's, in the mildly monopolistic approach sponsored by the Federal Farm Board in the early 1930's and in the more drastic program of acreage controls, marketing agreements and quota systems that came in 1933 and after.[17]

The objective of the farm programs of this period was to raise prices of farm products relative to nonfarm commodities and protect the equities of farmers who were in debt.[18] Coupled with these emergency programs were longer-term programs for soil conservation, improvement of credit facilities, and aid to low income farmers.

Beginning with 1941 and World War II, the emphasis of the government farm programs abruptly changed to increasing most types of production as much as possible. Thus the control programs were abandoned and incentive programs took their place. Circumstances were now reversed and the problem to a government waging war and attempting to control inflation at the same time was holding farm prices down.

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[17] Murray R. Benedict, Can We Solve the Farm Problem? (Baltimore, 1955), p. 7.

[18] Ibid., p. 12.

In a compromise move whereby agricultural representatives tacitly accepted price ceilings at parity,[19] the government guaranteed that prices of farm products would be supported at 90 percent of parity for two years after the close of the war. This measure, which was intended to prevent a reoccurence of the price drop following World War I, became the basis for later demands to continue to support farm prices at or near parity.[20] The expected slump did not materialize, and the Korean War kept up the favorable conditions for agriculture. Problems had not ceased to exist; they had merely changed form. As a result of favorable prices, farm output continued to expand and the government accumulated surplus stocks. Programs were initiated to reduce this buildup of surpluses. During the 1950's the programs were designed to influence farm production and resource use through establishment of controls on land inputs.

Specific programs of recent years have included the Soil Bank Act of 1956, which provided for an Acreage Reserve (terminated after 1958) and a Conservation Reserve providing for contracts of 3, 5, or 10 years to be made between 1956 and 1960. The Acreage Reserve was in effect for cotton, corn, wheat, rice, and tobacco during 1956-58 and for peanuts during 1956 only. Acreage removed from production by this program was estimated at 12.2, 21.4, and 17.2 million acres for the three years,

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[19] Parity of prices for agricultural products is defined in terms of purchasing power relative to that enjoyed during the 1910-14 period. The parity index is the ratio of prices received to prices paid and is the measure of this relative purchasing power. See U. S. Department of Agriculture, <u>Agricultural Prices</u>, SRS (Washington, 1964), pp. 42-43.

[20] Benedict, p. 14.

respectively.[21] The Conservation Reserve acreage during the 1956-60 period was 1.4, 6.4, 9.9, 22.4, and 28.4 million acres.[22] A review of these programs and analyses of their effects can be found in Economic Effects of Acreage Control Programs in the 1950's[23] and The Impact of Price Support Programs Upon the Available Supplies of Farm Products, 1948-56.[24]

The foregoing discussion points up the strong interrelations between agriculture and our economy as a whole. What happens to agricultural income is strongly influenced by government programs, national income and employment, inflationary trends and urban demands for land.

Objectives of This Study

The General Objective

Formulation of policy for commercial agriculture from a purely economic standpoint requires quantitative knowledge of the productivity of resources used in agriculture and the manner in which agriculture relates to other sectors of the economy. The general objective of this study is to investigate the productivity of aggregate farm inputs and to develop

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[21] U. S. Department of Agriculture, Farm Production-Trends, Prospects, and Programs, Agricultural Information Bulletin No. 239 (Washington, 1961), p. 29.

[22] Ibid.

[23] Raymond P. Christensen and Ronald O. Aines, Economic Effects of Acreage Control Programs in the 1950's, U. S. Department of Agriculture, Agricultural Economic Report No. 18 (Washington, 1962).

[24] Dale E. Hathaway and John F. Stollsteimer, The Impact of Price Support Programs Upon the Available Supplies of Farm Products, 1948-56, Michigan State University Technical Bulletin No. 277 (East Lansing, 1960).

a model which will allow prediction of the extent and direction of impacts on agriculture of postulated changes in the levels of variables such as government diversions of excess production, government payments to farmers, acreage controls, general price supports, unemployment, disposable income, and input prices.

Specific Objectives

Specific objectives of this study are to:

(1) Develop productivity coefficients (production elasticities) for nine groups of farm inputs and construct a series of aggregate production functions for the period 1932-1961.

(2) Estimate coefficients in a system of equations describing the demand for inputs used in agriculture.

(3) Construct a recursive economic model--including demand equations for inputs, the agricultural production function, and pertinent behavioral and institutional equations--to describe the economic structure of the agricultural sector.

(4) Use the recursive economic model to simulate the levels of selected variables over the period 1930-60 as a means of answering the following questions:

   (a) What is the long term impact of government programs on farm output, income, and employment?

   (b) What are the effects of changes in prices of inputs supplied by the nonfarm sector, national unemployment, and consumer disposable income on the farm economy?

   (c) What is the impact of different rates of technological advance on farm variables?

In the following chapter the use of the simulation technique in economic research is elaborated. Chapter III covers the estimation of productivity coefficients for farm inputs and the specification of an aggregate agricultural production function. The remaining equations in the model are estimated in Chapter IV, and the complete model in form for simulation is summarized. Testing of the predictive ability of the simulation model in Chapter V precedes the results of 15 simulations and a discussion of their implications in terms of the questions raised above. Chapter VI summarizes procedure, results and implications, limitations, and concludes with suggestions for further research.

The aspect of "the farm problem" to be treated in this study is based on the visualization of agriculture as an industry. Consequently the income problems of the agrarian segment with few resources and which produces only a small percentage of total output are not specifically considered.

CHAPTER II

SIMULATION AS A RESEARCH METHOD

Methods of analysis employing simulation have found extensive favor as tools of management science for industry. The construction of scale-model plant layouts is an example of the use of simulation, as are Monte Carlo analyses of the expected costs associated with maintenance of different machine systems. The reasoning underlying the use of simulation by industry is:

> Models and the process of simulation provide a convenient means whereby the decision maker may be provided with factual information regarding the operations under his control without disturbing the operations themselves. Thus, the simulation process is essentially one of indirect experimentation involving the testing of alternative courses of action before they are adopted.[1]

Simulation involves the application of logical reasoning to a scale model of selected real-world phenomena, whether the scale model be one of equations or the prototype of a physical plant. Obviously, simulation is not a well-defined technique such as linear programming, least squares, or other familiar tools of economic research. Rather, it is a general method of analysis that complements the more explicit techniques. As such it is coming increasingly into use in non-industrial applications.

The following quote provides a rationale for the application of

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[1] W. J. Fabrycky and Paul E. Torgerson, Operations Economy, (Englewood Cliffs, 1966), p. 20.

simulation to economic analyses:

> Mathematical models are largely restricted to forms unsuitable for nonlinear and dynamic phenomena that are significant in the process of economic development. Besides, most mathematical models are optimizing models. This implies that specific goals have to be set before the path of progress leading to the goals can be successfully laid down.
>
> Both of these difficulties can be obviated by resorting to simulation. The method not only permits the study of mutually interacting processes involving nonlinearities and time lags, but also does not require the assumption of optimum solutions.[2]

The complementarity between simulation and other explicit techniques can be seen if the simulation procedure is described as being composed of two major elements: (1) a specified dynamic system; and (2) variables whose values are to be evolved from the system. The first element may combine equations where the coefficients have been estimated by least squares or simultaneous techniques and may include linear programming or other sub-problems. As the second element, values of the variables involved can be traced through consecutive time periods, beginning with a set of specified conditions.

The following section summarizes the current applications of the simulation process to economic analyses.

A Review of Simulation Literature

Though simulation as an economic research tool is fairly new, a considerable amount of literature has developed on the subject. In the following paragraphs is a brief review of the literature involving the

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[2] Edward P. Holland and R. W. Gillespie, Experiments on a Simulated Underdeveloped Economy: Development Plans and Balance-of-Payments Policies, (Cambridge, 1963).

simulation of economic systems.

Babb and French[3] discuss the use of simulation procedures with particular reference to their potential for use by food processing firms. They distinguish between the broad characterization of simulation as model building (which is not new) and the use of measureable variables and quantitative methods such as Monte Carlo methods to generate a stream of behavior (which is new).

Halter and Dean have employed simulation as a decision-making aid for the operation of a large California cattle ranch. Formulation of expectations of prices is the main managerial policy tested, but implications for broader applications under conditions of uncertainty are stressed. "Validity of the model is tested by comparing computer results with all pertinent available knowledge about the actual system, and revising by increments until it is an acceptable representation of the real system."[4]

Zusman and Amiad[5] extend the application of simulation to farm planning under weather uncertainty. They attempt in their article to determine the optimal organization and managerial policies of a farm operating under low and unstable rainfall. The performance characteristics of various decision rules are evaluated by simulating the farm over a set

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[3] E. M. Babb and C. E. French, "Use of Simulation Procedures," Journal of Farm Economics, XLV (1963), pp. 876-877.

[4] A. N. Halter and G. W. Dean, "Use of Simulation in Evaluating Management Policies Under Uncertainty: Application to a Large Scale Ranch," Journal of Farm Economics, XLVII (1965), pp. 557-573.

[5] Pinhas Zusman and Amotz Amiad, "Simulation: A Tool for Farm Planning Under Conditions of Weather Uncertainty," Journal of Farm Economics, XLVII (1965), pp. 574-594.

of sampled sequences of years with weather events constituting the main stochastic inputs.

Crom and Maki[6] use a semi-annual model of the livestock-meat economy to illustrate five types of adjustments to improve the simulation model in terms of conformity to the real world situation. They emphasize that errors may accumulate sufficiently to render the model virtually useless for analysis and projection unless these adjustments are made.

A comprehensive, though brief, discussion of the development and use of simulation as a research tool is given in a 1960 article by Orcutt.[7] He covers models; the role of simulation; computer simulation of complex, large-scale systems; and discusses a demographic model of the U. S. household sector as a demonstration of the potential usefulness of simulation for models of economies built from micro-components.

Orcutt's article, the first of three in a simulation symposium, precedes articles by Shubik, and Clarkson and Simon. Shubik[8] discusses five areas of new interest to economics which depend on the advent of the high-speed digital computer. Among these are: (1) data processing; (2) analytical methods; (3) simulation; (4) gaming; and (5) artificial intelligence. Simulation is further classified as "tactical" (applied micro-economics, or operations research) and "strategic" (aspects of the whole economy, industry level, or firm level with part of its immediate

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[6] Richard J. Crom and Wilbur R. Maki, "Adjusting Dynamic Models to Improve Their Predictive Ability," <u>Journal of Farm Economics</u>, XLVII (1965), pp. 963-972.

[7] Guy H. Orcutt, "Simulation of Economic Systems," <u>American Economic Review</u>, L (1960), pp. 893-907.

[8] Martin Shubik, "Simulation of the Industry and the Firm," <u>American Economic Review</u>, L (1960), pp. 908-919.

environment). An important contribution of this paper is the review of investigations involving simulation, including references to some military uses of the technique.

Clarkson and Simon[9] deal with simulation as an aid to study of the theory of the firm and oligopoly theory, also pointing out the use in operations research and dynamic macroeconomics, particularly business cycle theory and "cobweb" theory. In the latter use they describe simulation as an additional technique for numerical analysis, permitting study of a system's behavior when initial conditions and parameters are varied, and allowing much larger systems to be formulated and studied than could be analyzed numerically without this tool.

Suttor and Crom[10] list some advantages of the use of simulation as: (1) allowing more complexity and realism than is possible in models which must be solved by conventional mathematical techniques; (2) allowing the construction of theories that take into account the qualitative aspects of human decision making; (3) usefulness in handling problems of aggregation; (4) ease of understanding by persons without advanced technical training in economics, mathematics, and statistics; and (5) ease of analysis of the effects of different assumptions on the solution. They suggest that the role of simulation in agricultural economics research can involve either theoretical or applied research. Applications cited include Harl's use of a simulator to trace the effects of linear

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[9] Geoffrey P. E. Clarkson and Herbert A. Simon, "Simulation of Individual and Group Behavior," American Economic Review, L (1960), pp. 920-932.

[10] Richard E. Suttor and Richard J. Crom, "Computer Models and Simulation," Journal of Farm Economics, XLVI (1964), pp. 1341-50.

programming solutions in studying the effects of alternative farm legal arrangements;[11] simulation runs of a price-output model of the livestock-meat economy;[12] and others already mentioned in this review.

In a discussion of Suttor and Crom's article, McKee[13] says that the simulation approach offers the economic researcher a feasible substitute for direct experimentation as a means of determining the probable effect of changes that might be imposed on the economic system of the real world. He points out that the most crucial problem in a simulation study involves the development of a representative economic model, which depends upon the model builder's knowledge and understanding of the functioning of the real world system. McKee disagrees with some of the statements of Suttor and Crom, particularly the point about a simulation model revealing the workings of the economic systems simulated. Instead, he says, the relationships existing among the components of the system are part of the assumptions, therefore the working of the economic system is assumed in building the model.

The Use of Simulation in This Study and the Theoretical Model

Relations between variables in agriculture, and between agriculture and the nonfarm sector are dynamic, and not always suited to analysis by

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[11] Neil E. Harl, unpublished research, Iowa State University, Ames, 1964.

[12] Richard J. Crom, "Computer Models of Price and Output Determination in the Livestock-Meat Economy," unpublished Ph.D. thesis, Iowa State University, Ames, 1964.

[13] Dean E. McKee, "Discussion: Computer Models and Simulation" Journal of Farm Economics, XLVI (1964), pp. 1350-52.

conventional quantitative techniques exclusively. Nor do "optimum" solutions specified by many models provide the information needed for workable policy decisions. What is needed is a quantitative procedure which can include time lags, nonlinearities, and recursive or reactive effects over a period long enough to give confidence in the stability potential of a model.

Simulation, as discussed earlier in this chapter, is such a procedure. The use of simulation in this study will be to generate a stream of values for twenty-four economic variables over the period 1930-1960. The starting point involves decisions by farmers to purchase inputs and allocate resources to production based on 1929 and 1930 data. Further decision rules are based on least squares regression coefficients, estimates of future levels of certain variables, and the known values of other variables.

Prior to discussing the model and procedure in specific detail, let us refer to a generalized flow diagram of the model, as in Figure 1. This type of diagram (Figure 1) is the initial step in formulating the model and in writing the computer program to perform the calculations. Block A consists of seven behavioral equations and three identities. The seven variables estimated are (1) acres of cropland used for crops in year <u>t</u>, (2) crop and livestock inventory at the beginning of year <u>t + 1</u>, (3) stock of productive assets at the beginning of year <u>t + 1</u>, (4) purchases of machinery during year <u>t</u>, (5) stock of machinery at the beginning of year <u>t + 1</u>, (6) price of real estate during year <u>t</u>, and (7) total value of real estate during year <u>t</u>. The three identities define average levels of crop and livestock inventory, stock of productive assets, and stock of machinery.

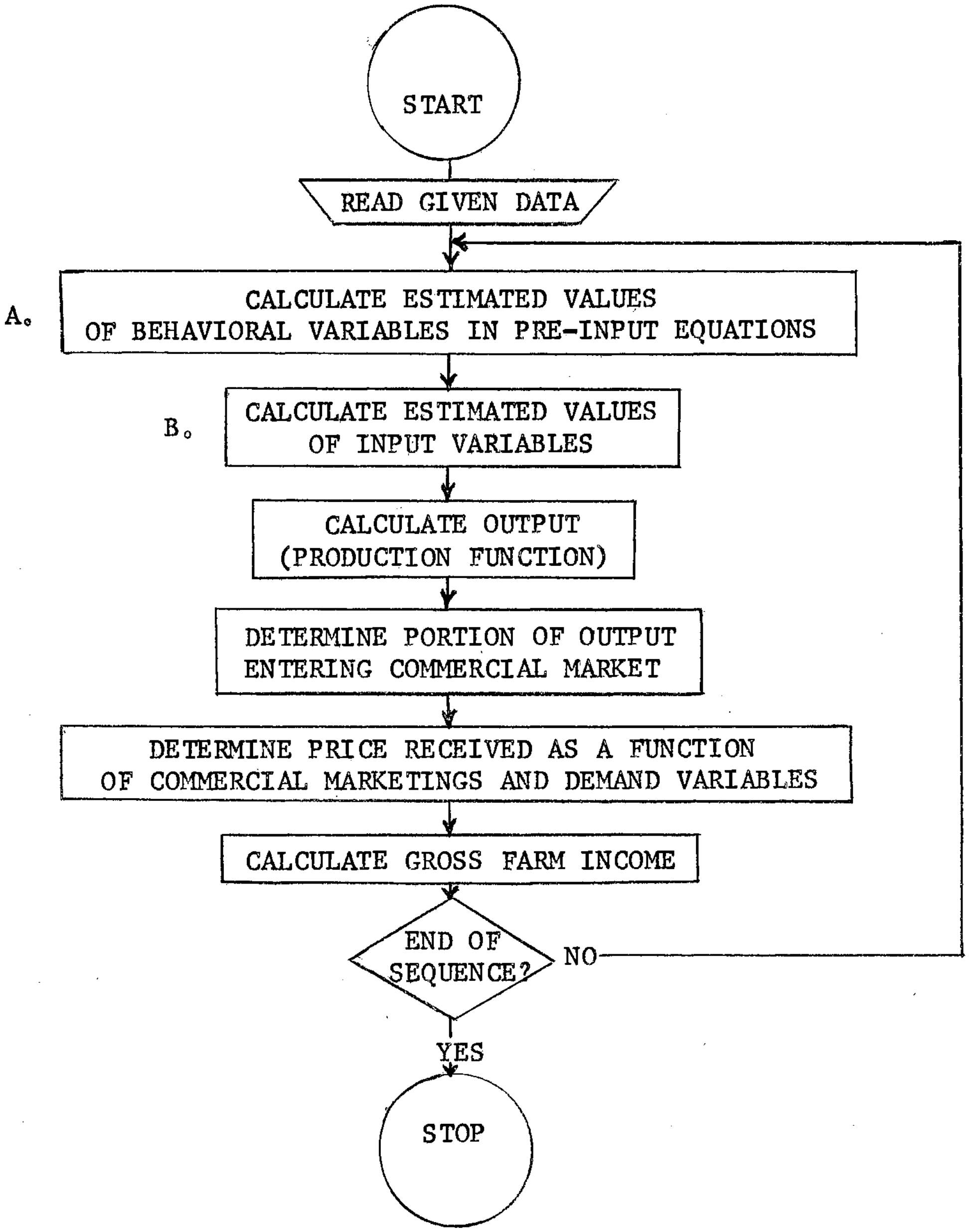

Figure 1. Generalized Flow Diagram of the Simulation Model

Although the equations are grouped in one block, they still retain recursive aspects. That is, estimated purchases are included in the stock of machinery equation, the estimated price of real estate becomes a variable in the value of real estate equation, and the three estimates for t + 1 enter into the identities.

The estimates from block A feed into various equations in block B, either directly or indirectly. Block B consists of ten equations and provides estimates of the levels of nine agricultural input groups. The input groups are (1) expenditures for fertilizer and lime, (2) feed, seed, and livestock expenditures, (3) labor expense, (4) machinery ownership expense, (5) real estate expense, (6) fuel and machinery operating charges, (7) miscellaneous current operating expense, (8) interest on crop and livestock inventories, and (9) real estate taxes. (Input categories are described in the following chapter.)

All of the estimates from block B feed into the appropriate production function (1930-41, 1942-51, or 1952-60) as the next step, and the estimated output for year t results. The commercial market quantity is defined as output minus: (1) home consumption, (2) changes in inventories on farms, and (3) government diversions. The aggregate commodity demand function enters next, using the commercial marketings from the preceding equation, and exogenous data on population, income, and prices of other consumer goods. The final equation specifies gross farm income as a function of the quantity of commercial marketings, prices received by farmers, and government payments to farmers.

This completes the cycle for one year, and the simulation begins again at block A for the next cycle, using both actual data and estimates from the preceding cycle, until the desired number of years have been simulated.

The equations in implicit and estimated forms will be presented in the ensuing two chapters, with the complete detailed model given at the end of Chapter IV.

Restating the intent of the simulation model briefly--it is expected that the model developed will be revised until it generates estimates that are satisfactory approximations of the observed series, thus providing a vehicle for the analysis of the effects of postulated changes in the data series used. Analytical employment of the simulation model is undertaken in Chapter V.

CHAPTER III

PRODUCTIVITY OF AGRICULTURAL INPUTS

The present and past discrepancies between the production and utilization of farm products evidences the need for more quantitative knowledge of the relationship between farm inputs and aggregate production. The adoption of new technology by farmers has increased the productivity of conventional resources tremendously, and the combination of a relatively stable bundle of resources with this productivity increase has resulted in an output which exceeds foreign and domestic demands at acceptable prices.

In order to develop a model of the agricultural sector for determining the effects of various alternative policies on input use, output, prices, and income, estimates of the input productivity coefficients are required. The purpose of this chapter is to develop estimates of the elasticities of production[1] for nine groups of agricultural inputs and specify an aggregate production function.

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[1] The elasticity of production of an input X used in producing Y is defined as the percent change in Y resulting from a one percent change in X, and is expressed mathematically as $\frac{\partial Y}{\partial X} \cdot \frac{X}{Y}$.

A Method for the Estimation of Production Elasticities[2]

Adjustment Model Hypothesis

The traditional estimating approach has been the derivation of production elasticities from a directly estimated least squares production function,[3] usually using time series data. Among the problems encountered by researchers using direct least squares is that of highly correlated "independent" variables. It is not possible to directly estimate from time series the production elasticities for a function such as

$$Y = aX_1^{b_1}X_2^{b_2}\ldots X_n^{b_n} \tag{1}$$

because of high correlations between the data series X_i.[4] Therefore, output is usually regressed on a limited number of highly aggregated variables, with the result that output is "described"; however, the usefulness of estimated coefficients is greatly lessened due to the degree of aggregation.

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[2] Much of the material for this section has been developed from drafts of a paper presented at the 1965 meetings of the American Farm Economics Association at Stillwater, Oklahoma: Fred H. Tyner and Luther G. Tweeten, "A Methodology for Estimating Production Parameters," Journal of Farm Economics, XLVII (1965), pp. 1462-67.

[3] Zvi Griliches, "Estimates of the Aggregate Agricultural Production Function from Cross-Section Data," Journal of Farm Economics, XLV (1963), pp. 419-428; Earl O. Heady and Luther G. Tweeten, Resource Demand and Structure of the Agricultural Industry (Ames, 1963), Chapter 4; and Earl O. Heady and John L. Dillon, Agricultural Production Functions (Ames, 1961).

[4] Simple correlation coefficients (there are $9!/2!7! = 36$ correlations) for the nine categories considered in this study were .73, .83 ..., .99. The matrix of sums of squares is then so nearly singular as to give highly dubious results.

A second approach is to estimate the production function from cross-sectional data by least squares, but this procedure does not accommodate the very important dynamic features of the production function.

Another approach is the use of factor shares[5] as an instrument for analysis of the functional distribution of income and factor productivity. The earliest published work in this area was by W. I. King,[6] with recent extensive work on factor shares in agriculture carried out by Ruttan, Stout, and MacEachern.[7]

The factor share approach avoids the least squares problem of multicollinearity and allows greater disaggregation. However, a major limitation of the usual factor share approach is the assumption of economic equilibrium in order for the current factor share to be a valid measure of current productivity. If disequilibrium exists, or if factor productivity is changing, then the use of factor shares as production

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[5] The factor share is defined as the ratio of expenditure on an input to the value of output. In common usage a linearly homogeneous production function is assumed, and the application of Euler's theorem (See George Stigler, *Production and Distribution Theories* (New York, 1941), pp. 325) results in each factor receiving its marginal value product. This condition can be expressed as $\partial Y/\partial X = P_x/P_y$, which is the competitive equilibrium condition. Multiplying through by X/Y gives the elasticity of production on the left equal to the factor share on the right.

[6] W. I. King, *Wealth and Income of the People of the U. S.* (London, 1915), pp. 154-57.

[7] V. W. Ruttan and T. T. Stout, "Regional Differences in Factor Shares in American Agriculture: 1925-57", *Journal of Farm Economics*, XLII (1960), pp. 52-68; T. T. Stout and V. W. Ruttan, "Regional Patterns of Technological Change in American Agriculture," *Journal of Farm Economics*, XL (1958), pp. 196-207; and G. A. MacEachern and V. W. Ruttan, "National and Regional Changes in Factor Shares in American Agriculture: Concepts, Measurement, and Implications," paper presented to conference on "Farmers in the Market Economy," Iowa State University Center for Agricultural and Economic Adjustment, Ames, May, 1963.

elasticities to estimate least-cost or equilibrium input levels is chronologically incorrect.

The estimation procedure employed in this section is an attempt to combine favorable features of the least squares and factor share approaches. The current factor share is used as a beginning estimate of productivity, but an adjustment model which assumes only a tendency towards equilibrium permits estimation of equilibrium production parameters from a disequilibrium current factor share structure.

The equality of the factor share and elasticity of production under equilibrium conditions is shown in footnote 5. The adjustment model referred to in the preceeding paragraph is developed from the following reasoning: The process of adjustment in resource use at the farm level is not instantaneous (within a production period) because of risk, uncertainity, technical restraints, institutional rigidities, and psychological resistance to change.[8] Ideally, the farmer considers his resource situation in year t and formulates a "better" utilization of his resources for year (or production period) t+1, based on his subjective estimate of the optimum. This process of adjustment can be formalized into a model such as

$$(2) \qquad F_t - F_{t-1} = g(E^*_t - F_{t-1}), \qquad 0 < g < 1$$

which states that the change in factor use is some proportion, g, of the desired adjustment (divergence from equilibrium), since in equilibrium

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[8] Cf. Marc Nerlove, Distributed Lags and Demand Analysis for Agricultural and Other Commodities, Agricultural Handbook No. 141, U. S. Department of Agriculture (Washington, 1958), for a discussion of adjustment models and reasons for lags in response.

$E^* = F$. The coefficient g is restricted to the interval $0 < g < 1$ because of the hypothesized tendency toward equilibrium and the lag in response. F_t is the current factor share and E^*_t is the current equilibrium factor share (elasticity of production). Given the assumption that each firm is striving for maximum efficiency, E^*_t can be estimated by least squares. Let the first difference of the factor share, $F_t - F_{t-1}$, be designated ΔF_t, and the gE^*_t term as A. Then (2) can be written as

$$\Delta F_t = A - gF_{t-1}, \tag{3}$$

where ΔF_t is the dependent variable, A is the constant, and g is the coefficient of the independent variable F_{t-1}. Since A and g are the least squares estimates, E^*_t can be estimated as $E^*_t = A/g$.

Modification of the Basic Adjustment Model

Equation (2) implies constancy in the adjustment rate, g, and also in the equilibrium elasticity, E^*_t. However, due to the multitude of technological advances made in agricultural production in the last half century, it is unlikely that the productivity of all the conventional input categories used in this study has remained constant. In order to allow for consideration of a changing elasticity of production the following equation was used:[9]

$$F_t - F_{t-1} = g\ [(E' + \sum_{1}^{4} d_i D_i - F_{t-1}], \tag{4}$$

where $D_1 = 1$ in each year 1912-21, zero elsewhere,

$D_2 = 1$ in each year 1922-31, zero elsewhere,

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[9] Production elasticities were estimated by decades beginning with 1912-21. Only estimates for the 1932-41 and later decades are used in this study for simulation analysis.

$D_3 = 1$ in each year 1932-41, zero elsewhere,

$D_4 = 1$ in each year 1942-51, zero elsewhere.

Equation (4) replaces E^*_t with its hypothesized equivalent, $E' + \sum_1^4 d_i D_i$, allowing E^*_t to vary between decades depending on the d_i values. The estimates are $E^*_{1912-21} = E' + d_1$; $E^*_{1922-31} = E' + d_2$; $E^*_{1932-41} = E' + d_3$; and $E^*_{1942-51} = E' + d_4$. The estimate $E^*_{1952-61}$ is simply E'.[10] Again, E' is determined by dividing the intercept term (A) in the least squares equation by the coefficient (g) of F_{t-1}.

Another hypothesis is that the rate of adjustment is not constant for a particular factor X_i, but depends on some other variable measuring (for instance) relative prices, income levels, expectations, etc. Assuming E^*_t is constant, this hypothesis may be tested with a model such as

$$(5) \qquad F_t - F_{t-1} = (g' + hP_{t-1})\,(E^*_t - F_{t-1}),$$

where the rate of adjustment, g, is a linear function $(g' + hP_{t-1})$ of the parity ratio or other relevant variable. The g' term represents the permanent component of adjustment and h the effect of the behavioristic variable.

While the linear g-relation may not be the most appropriate, simplicity and convenience suggest its use. The constant E^*_t assumption is required in this case for estimational feasibility, i.e., to prevent over-identification[11] and multicollinearity problems. For example,

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[10] J. Johnston, Econometric Methods (New York, 1963), pp. 221-228, explains this application of dummy variables.

[11] Over-identification in the sense that multiple estimates for the same parameter are obtained.

substitution of $E_t^* = E' + \sum_1^4 d_i D_i$ in (5) gives 11 least squares coefficients when there are only seven parameter estimates required.

An additional variation allows a proportionate change rather than an absolute change in the factor share by reformulating equations (4) and (5) as (6) and (7), respectively:

$$(6) \qquad \frac{F_t}{F_{t-1}} = \left[\frac{E' \prod_1^4 D_i^{d_i}}{F_{t-1}} \right]^g ;$$

$$(7) \qquad \frac{F_t}{F_{t-1}} = \left[\frac{E_t^*}{F_{t-1}} \right]^{(g' + hP_{t-1})} .$$

Taking logarithms of both equations gives equations (8) and (9),

$$(8) \qquad \log F_t - \log F_{t-1} = g[(\log E' + \sum_1^4 d_i \log D_i) - \log F_{t-1}]$$

$$(9) \qquad \log F_t - \log F_{t-1} = (g' + hP_{t-1})(\log E_t^* - \log F_{t-1})$$

which corresponds to equations (4) and (5) except for the use of logarithmic data for factor shares. Also, the dummy variables in (8) and (9) are equal to 10 in the appropriate decades rather than 1 as in their arithmetic counterparts.

Use of Autoregressive Least Squares (ALS)[12]

Economists using time-series data have recognized autocorrelated disturbances (errors) as an important problem in obtaining accurate parameter estimates. However, due to the problems involved in describing

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[12] Appreciation is due Dr. James E. Martin, Professor, Department of Agricultural Economics, Oklahoma State University, for adapting his ALS computer program for this problem and for much additional assistance rendered on the ALS technique.

the influence of the error term, most applied work relies on the assumption that disturbances in successive time periods are random (statistically independent). The equations in the preceding section were first estimated by least squares, but examination of the residuals indicated the likelihood of autocorrelation.

Hildreth and Lu have pointed out the effects of autocorrelated errors by re-estimating the coefficients of 22 linear demand equations estimated by other authors.[13] Fuller and Martin later developed an iterative procedure described as Autoregressive Least Squares (ALS) which gave improvements in accuracy, provided statistical tests of the autocorrelation coefficient, and reduced extensively the calculation time over the Hildreth-Lu procedure.[14]

The basic model (equation 2) was presented without the usual assumption of a normally-distributed error term, e_t. The above type of equation tends to possess an autocorrelated error term when estimated by conventional least squares, with the result that parameter estimates are biased and inefficient. The ALS technique is used in this study as a method for obtaining additional and, hopefully, improved estimates of production parameters.

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[13] Clifford Hildreth and John Y. Lu, Demand Relations with Auto-Correlated Distrubances, Michigan State University Technical Bulletin No. 276, (East Lansing, 1960).

[14] Wayne A. Fuller and James E. Martin, "The Effects of Autocorrelated Errors on the Statistical Estimation of Distributed Lag Models," Journal of Farm Economics, XLIII (1961), pp. 71-82; and "A Note on the Effects ...," Journal of Farm Economics, XLIV (1962), pp. 407-410. Detailed comparisons of Hildreth-Lu and autoregressive least squares estimates are presented in George W. Ladd and James E. Martin, Application of Distributed Lag and Autocorrelated Error Models to Short-Run Demand Analysis, Iowa State University Research Bulletin No. 526 (Ames, 1964).

If autocorrelation exists, the autocorrelated error term u_t is added to equation (2) to get (10):

$$F_t - F_{t-1} = g(E^*_t - F_{t-1}) + u_t. \tag{10}$$

The simplest assumption regarding autocorrelated errors is the first order scheme in (11),

$$u_t = \beta u_{t-1} + e_t \tag{11}$$

where β is the autocorrelation coefficient and e_t is normally distributed.

The estimate of β is obtained by the ALS procedure. To derive the equation to be estimated, lag (10) and multiply by β for (12):

$$\beta F_{t-1} - \beta F_{t-2} = g\ \beta E^*_{t-1} - g\beta F_{t-2} + \beta u_{t-1}. \tag{12}$$

Solve (12) for βu_{t-1}, giving (13):

$$\beta u_{t-1} = \beta F_{t-1} - \beta(1-g)F_{t-2} - g\beta E^*_{t-1}. \tag{13}$$

Substituting equation (13) into (11) and the result into (10), and finally rearranging terms gives (14):

$$\begin{aligned} F_t = {} & g(E^*_t - \beta E^*_{t-1}) + (1 - g + \beta)F_{t-1} \\ & - (1 - g)\beta F_{t-2} + e_t, \end{aligned} \tag{14}$$

which is the equation to be estimated by ALS.[15]

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[15] With the substitution $E^*_t = E'_t + \sum_1^4 d_i D_i$, the equation becomes:

$$F_t = g(E'_t - \beta E'_{t-1}) + g\left(\sum_1^4 d_i D_{i_t} - \beta\sum_1^4 d_i D_{i_{t-1}}\right) + (1-g+\beta)F_{t-1} - (1-g)\beta F_{t-2} + e_t.$$

Estimates of g, β, d_i, and A [the constant term: $(gE'_t - \beta E'_{t-1})$] are derived directly from the ALS procedure. Assuming $E'_t = E'_{t-1}$, E' is calculated as $E' = A/g(1 - \beta)$.

Estimation of Production Elasticities

Selection of Input Groups

Input categories for which production elasticities were estimated are those used by the Farm Production Economics Division, U. S. Department of Agriculture, for aggregating input costs. The categories chosen cover the range of farm actual and opportunity costs:

1. expenditures for fertilizer and lime,
2. purchases of feed, seed, and livestock from the nonfarm sector (essentially marketing charges),
3. labor expense (with family and operator labor priced at the hired labor wage rate),
4. machinery expense (annual interest charge on machinery investment plus depreciation of motor vehicles and other machinery and equipment),
5. real estate expense (interest charge on real estate investment plus building depreciation, accident damage, repairs, and maintenance),
6. fuel, operation, and repairs of machinery,
7. miscellaneous current operating expenses,
8. interest on crop and livestock inventories,
9. real estate taxes.

Expenditures on operating inputs are market cash costs. Expenditures on durables such as land and machinery are the depreciation and opportunity interest charge necessary to maintain these inputs at the current level. Family labor is assumed to be paid the hired labor wage rate. Thus, inputs are valued at actual or opportunity cost, and no input takes a residual return.

All inputs were used as reported in current dollar value or were adjusted to current dollar value if reported in constant dollars. Data sources and adjustments are given in Appendix A, Table I.

Calculation of Factor Shares

Using data for the 1910-61 period, factor shares were calculated for each input by dividing the annual expense estimate by adjusted gross farm income (gross income less government payments, less adjustments for inter-farm sales of feed, seed, and livestock). The factor shares data are not presented separately since they are calculated directly from the data in Appendix A, Table I, but trends in factor shares for the period 1910-61 are graphed in Figures 2, 3, and 4.

If factor use were in equilibrium in each year, the factor shares would sum to one annually, given constant returns to scale. This is a requirement sometimes imposed on estimates of factor shares, and corresponding adjustments are made, including assigning labor a residual share. In this study no such requirement is set, as explained above by the method of calculating actual and opportunity costs.

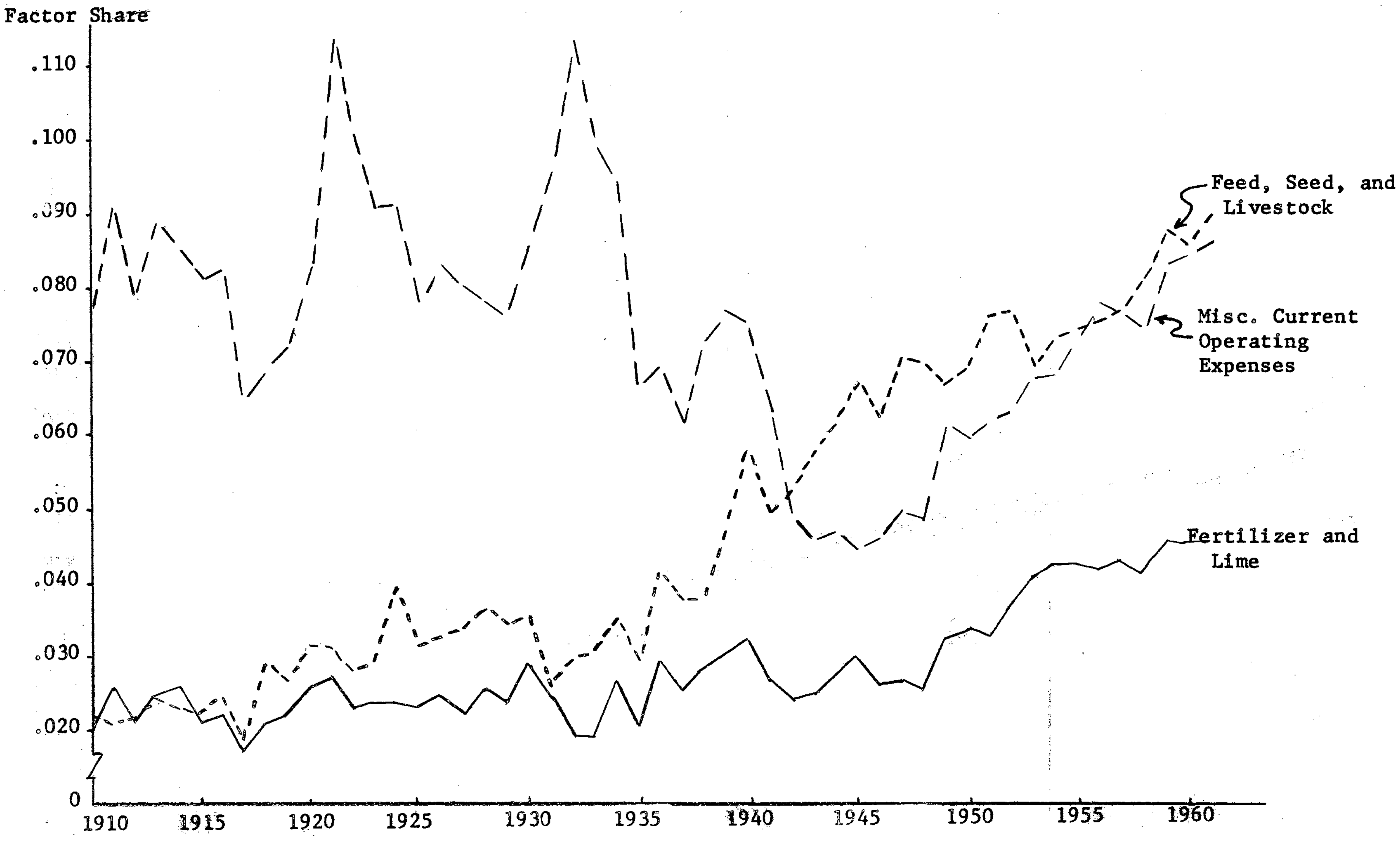

Figure 2. Factor shares for selected input categories, U. S. agriculture, 1910-61.

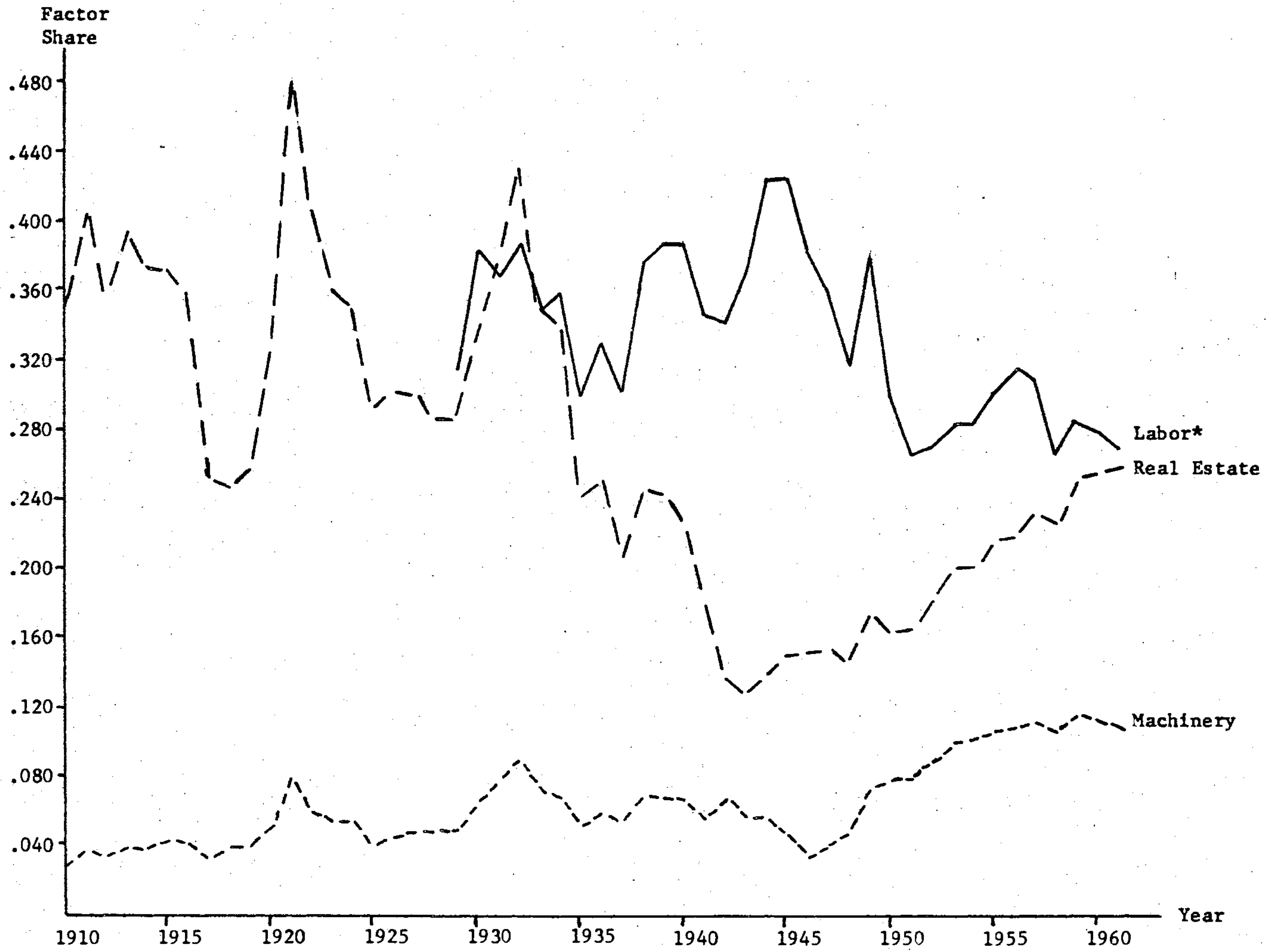

Figure 3. Factor shares for selected input categories, U. S. agriculture, 1910-61.
*Data not available prior to 1929.

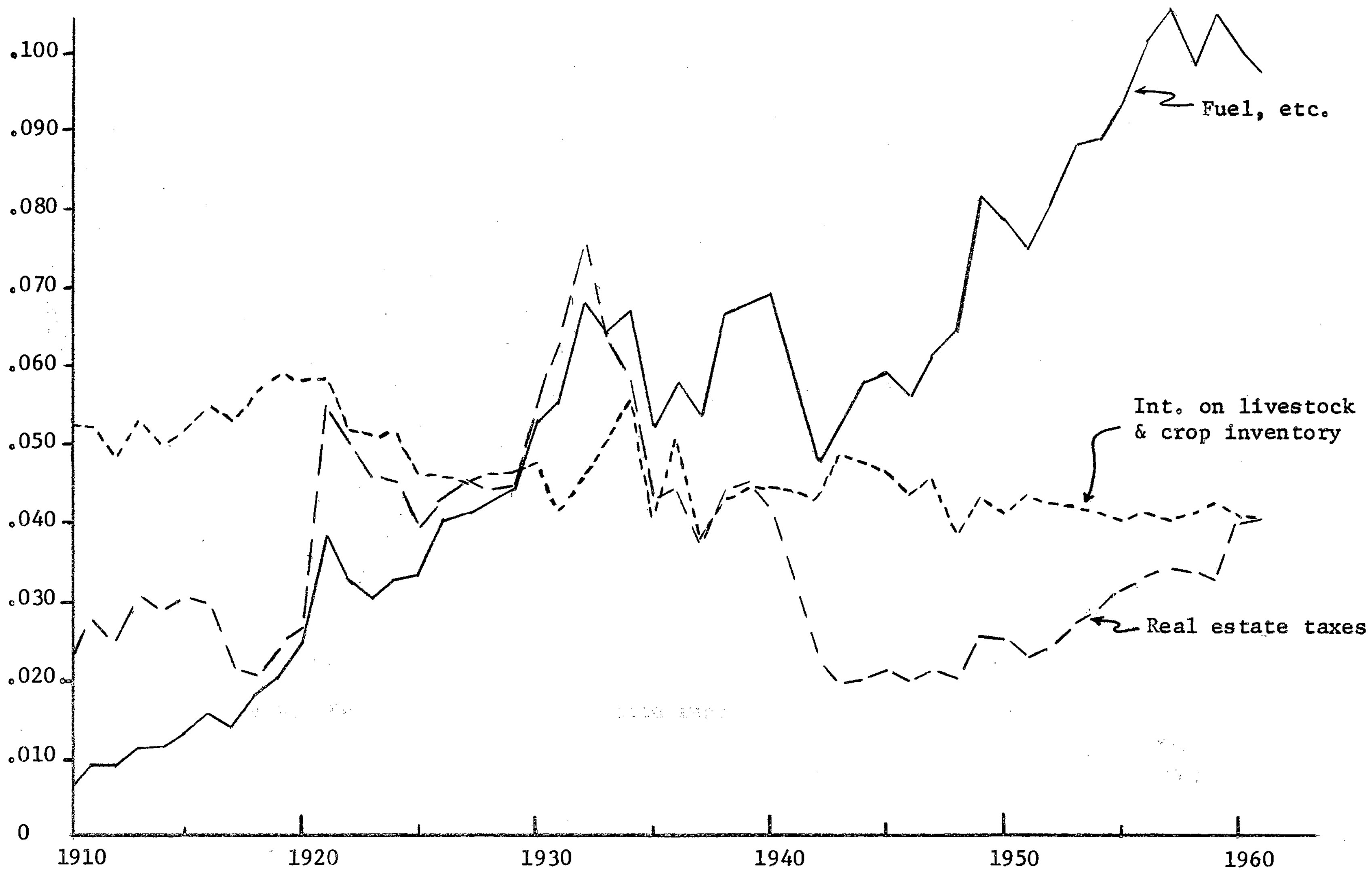

Figure 4. Factor shares for selected input categories, U. S. agriculture, 1910-61.

Elasticity Estimates Obtained

The equations discussed previously in this chapter were estimated by both ordinary least squares (LS) and autoregressive least squares (ALS) techniques. Comparison of the results indicated that equations which allowed for a changing elasticity of production were the most promising; i. e., equations (4) and (6):

$$F_t - F_{t-1} = g[(E' + \sum_{1}^{4} d_i D_i) - F_{t-1}] \tag{4}$$

$$\frac{F_t}{F_{t-1}} = \left[\frac{E' \prod_{1}^{4} D_i^{d_i}}{F_{t-1}} \right]^g \tag{6}$$

The coefficients of adjustment and coefficients of dummy variables often differed considerably between the LS and ALS runs. As a criterion for choosing between the LS and ALS formulations, it seemed logical to use the ALS estimates (other things reasonably constant) where β, the coefficient of autocorrelation, tested significantly different from zero. Table I shows the estimated β values for arithmetic and logarithmic equations and indicates their significance levels based on Student's t-test of the hypothesis $\beta = 0$.[16]

Table I indicates that autocorrelation was found to be a significant problem in nine of the 18 equations estimated by ALS. Estimation of equation (4) in original values by LS for inputs 2, 3, 4, and 8, and

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[16] A calculated t-value [$(\hat{\beta} - \beta)/\sqrt{\text{variance } (\hat{\beta})}$] greater than the tabular t-value (5% level, appropriate degrees of freedom) indicates that rejection of the null hypothesis, $\beta = 0$, is in order since the probability of a calculated $t \geq t_{.05}$ is .05 or less if the null hypothesis is true. Student's t-test is explained in most texts on inferential statistics: Cf. Robert G. D. Steel and James H. Torrie, <u>Principles and Procedures of Statistics</u> (New York, 1960).

TABLE I

AUTOCORRELATION COEFFICIENTS ($\hat{\beta}$) ESTIMATED FOR EQUATIONS RUN IN ORIGINAL VALUES AND LOGARITHMS (1912-61)

	Input Group[a]								
Item	1	2	3	4	5	6	7	8	9
				(Original)					
$\hat{\beta}$	-.08464	-.37753	.40411	.82086	.13304	.07942	.16969	-.55555	.25052
t^b	0.42	2.73*	3.27**	7.86**	0.57	0.47	0.67	4.05**	1.13
				(Logarithms)					
$\hat{\beta}$	-.06539	-.47373	.41122	.76889	.20246	-.07927	.20234	-.06789	.17441
t^b	0.93	4.56**	2.47*	15.44*	1.70	c	1.73	3.65**	5.71**

[a] Corresponds to numbering of input groups under "Selection of Input Groups" above.

[b] Calculated t-values, 44 degrees of freedom.

[c] No solution obtained. Logarithmic data gave a singular matrix.

*,**Indicates significance at 5 and 1 percent levels, respectively.

in logarithms for inputs 2, 3, 4, 8, and 9 would likely have resulted in biased coefficient estimates due to the failure of the error term to meet the assumptions of the general LS model. Use of these results in selecting the estimating equation to use for each input category will be made after consideration of additional criteria.

Where the estimate of β did not differ significantly from zero, the ALS specification may still improve the fit of the equation by reducing the residual sum of squares and providing more precise estimates of the other parameters. An appropriate method for evaluating this hypothesis is an F-test based on reduction in the residual sum of squares.[17] The test made was:

$$F = \frac{SSE_{ls} - SSE_{als}}{MSE_{als}} \quad ,$$

where

SSE_{ls} = LS residual sum of squares,

SSE_{als} = ALS residual sum of squares,

MSE_{als} = ALS residual mean square,

and F has 1 and 44 degrees of freedom.

The results of the F-test are shown in Table II.[18] LS and ALS equations were compared both in original and logarithmic variables for each input group.

Table II indicates that the regression sum of squares was increased significantly by the ALS specification for inputs 2, 4, 7, 8, and 9 using original data, and for inputs 2 and 4 using logarithmic data. In only two of these cases - inputs 7 and 9, original data - was the β estimate shown in Table I not significantly different from zero. Consideration will be given to these results in the later discussion of the contents of Table IV.

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[17] The test used is comparable to analysis of variance testing of the contribution of additional variables in a regression model, Cf. Steel and Torrie, p. 288. The numerator is equivalent to the addition to the regression sum of squares due to the ALS specification since the total sum of squares is the same: $(SST - SSE_{als}) - (SST - SSE_{ls}) = SSE_{ls} - SSE_{als}$.

[18] Calculated F-values are compared with tabular values of F at the 5% level for 1 and 44 degrees of freedom. If calculated $F > F_{.05}$ there are fewer than 5 chances in 100 that the disparity in the size of the two variances represented by the numerator and denominator is due to chance. Consequently, the reduction in SSE is judged to be significant.

TABLE II

RESULTS OF F-TESTS FOR EVALUATING REDUCTION IN RESIDUAL SUM OF SQUARES BETWEEN LS AND ALS EQUATIONS

Item	Input Group[a]								
	1	2	3	4	5	6	7	8	9
					(Original)				
F	0.26	4.10*	0.86	5.37*	0.52	0.17	51.66**	106.06**	80.82**
					(Lorarithms)				
F	0.12	6.23*	0.74	4.86*	1.52	b	1.00	0.39	4.67

[a] Corresponds to numbwring of input groups under "Selection of Input Groups" above.

[b] No solution obtained. Logarithmic data gave a singular matrix.

*,**Indicates significance at 5 and 1 percent levels, respectively. Appropriate degrees of freedom are 1 and 44.

An added criterion for selection of a single equation for each input group is significance of the adjustment coefficient, g. Significance levels of g in the LS and ALS equations are indicated in Table III. (The coefficient appears as 1-g in the LS specification, but estimation by the ALS procedure with $\beta = 0$ gives the LS estimates of g and the other parameters and also provides a direct test of g.)

The basic adjustment model allowed a gradual adjustment of inputs to equilibrium. However, the adjustment of factor use to equilibrium was not indicated to occur unless the estimated g-value was significantly different from zero. Table III indicates g-values exceeded zero in all but nine of the 36 cases (including two cases where no estimate of g was obtained).

TABLE III

COMPARISON OF ADJUSTMENT COEFFICIENTS ESTIMATED BY LS AND ALS PROCEDURES USING ORIGINAL VALUES AND LOGARITHMS

Input[a]	L.S.		A.L.S.	
	Original	Logarithms	Original	Logarithms
1 CH	.59844**	.66073**	.53540**	.60492**
2 FSL	.30430**	.43791**	.09961	.11301
3 LA	.45774*	.44995*	.85986**	.87717**
4 MC	.29894*	.28921*	.75537**	.77901**
5 RE	.33972**	.31300**	.39749*	.39648**
6 EN	.23108*	b	.27880	c
7 MI	.35770*	.36937**	.44789	.47412**
8 RE, MA	.77691**	.82663**	.39132**	.77788**
9	.19157	.26055	.31788	.44799**

[a] Corresponds to numbering of input groups under "Selection of Input Groups" above.

[b] Estimated g was negative.

[c] No solution obtained. Logarithmic data gave a singular matrix.

*,**Indicates significance of g at levels of 5 and 1 percent, respectively. The test criterion was Student's t-test with 45 degrees of freedom for LS equations and 44 degrees of freedom for ALS equations based on the null hypothesis g = 0.

Table IV adds the coefficient of determination, R^2, (proportion of the variation in the dependent variable accounted for by the regression specification) to the previously discussed criteria for selection of an estimating equation for each input category. The heirarchy of criteria is generally as follows:

1. Select ALS equation if β significant. (Choose between original and logarithmic specification on basis of β, g, and R^2).
2. Select ALS equation if β not different from zero but SSE is significantly reduced.

TABLE IV

COEFFICIENTS OF DETERMINATION AND ASSOCIATED CRITERIA FOR SELECTION OF BEST EQUATION

Input[a]	Equation Type and Data			
	L.S.		A.L.S.	
	0	L	0	L
		Coefficient of Determination (R^2)		
1	$\underline{\underline{.87}}$	$\underline{\underline{.80}}$	$\underline{\underline{.87}}$	$\underline{\underline{.80}}$
2	$\underline{\underline{.95}}$	$\underline{\underline{.93}}$	.96*,+	.94**,+
3	$\underline{.57}$	$\underline{.58}$	$\underline{\underline{.59}}$**	$\underline{\underline{.59}}$*
4	$\underline{.86}$	$\underline{.81}$	$\underline{\underline{.87}}$**,+	$\underline{\underline{.83}}$**,+
5	$\underline{\underline{.81}}$	$\underline{\underline{.87}}$	$\underline{.82}$	$\underline{\underline{.88}}$
6	$\underline{.95}$	b	.95	c
7	$\underline{.41}$	$\underline{\underline{.78}}$	$\underline{.73}$++	$\underline{\underline{.79}}$
8	$\underline{\underline{.44}}$	$\underline{\underline{.64}}$	$\underline{\underline{.72}}$*,++	$\underline{\underline{.64}}$**
9	.46	.83	.81++	$\underline{\underline{.85}}$**,+

[a] Corresponds to numbering of input groups under "Selection of Input Groups" above.

[b] Estimated g was negative.

[c] No estimate obtained. See footnote c, Table III.

*,**Indicates significance of β at 5 and 1 percent levels, respectively. (From Table I)

+,++Indicates a significant reduction in residual sum of squares over L. S. equation (5 and 1 percent levels, respectively). (From Table II)

$\underline{\quad}$, $\underline{\underline{\quad}}$ Indicates significance of the adjustment coefficient g (5 and 1 percent levels, respectively) (From Table III).

3. Select LS equation if (1) and (2) are not conclusive, deciding between original and logarithmic specification on basis of g and R^2.

Table V presents the equations selected and shows the associated production elasticity estimates. The basis of selection for input categories 1, 2, 3, 4, 6, 8, and 9 is generally apparent from the heirarchy given above. For inputs 5 and 7, selection of A.L.S.(L) over L.S.(L) was arbitrary, with little difference noted in the production elasticity estimates.

The direction of change in the estimated elasticities over time seems consistent with observed evidence of input productivity; i.e., increases for fertilizer, machinery, and fuel and operating expenses; and decreases for labor and real estate. For the 1932-61 estimates, which are to be used in the simulation model, the fertilizer elasticity of production increased from .026 to .043; the productivity of feed, seed, and livestock purchased for production increased from .062 to .089; machinery productivity increased from .061 to .094; and the fuel and operating expenses of machinery production elasticity rose from .065 to .103. The labor production elasticity estimates decreased from .348 to .290 from 1932-41 to 1952-61. Inputs whose estimated productivity remained relatively constant over the 30 year period were interest on crop and livestock inventory (.046 to .041) and real estate taxes (.039 to .035). Real estate production was about equal in 1932-41 and 1952-61, but showed a considerable decrease during the war and post-war period of the 1940's, suggesting that a scarcity of variable resources may have caused a confounding of the productivities of the various factors.

TABLE V

SELECTED ESTIMATES OF PRODUCTION ELASTICITIES BY DECADES AND CORRESPONDING AVERAGE FACTOR SHARES

Input[a]	Equation[b]	Item	1912-21	1922-31	1932-41	1942-51	1952-61
1.	L.S.(O)	E^*_t	.02237	.02400	.02648	.02885	.04325
		Avg.FS	.02275	.02428	.02600	.02828	.04235
2.	A.L.S.(L)	E^*_t	.03256	.03067	.06165	.08766	.08862
		Avg.FS	.02537	.03278	.03971	.06557	.07945
3.	A.L.S.(O)	E^*_t	c	c	.34777	.34458	.28983
		Avg.FS	c	c	.35273	.35339	.28555
4.	A.L.S.(O)	E^*_t	.07813	.04648	.06056	.07768	.09408
		Avg.FS	.04433	.05399	.06482	.05725	.10392
5.	A.L.S.(L)	E^*_t	.34449	.30206	.23619	.14837	.23816
		Avg.FS	.34176	.33018	.27106	.14940	.22238
6.	L.S.(O)	E^*_t	.02698	.04722	.06513	.06901	.10321
		Avg.FS	.01815	.04092	.06300	.06394	.09625
7.	A.L.S.(L)	E^*_t	.08296	.08187	.07550	.05133	.07793
		Avg.FS	.08177	.08617	.07968	.05135	.07552
8.	A.L.S.(O)	E^*_t	.05605	.04560	.04587	.04441	.04112
		Avg.FS	.04912	.04761	.04596	.04454	.04163
9.	A.L.S.(L)	E^*_t	.03200	.04682	.03861	.02112	.03542
		Avg.FS	.02998	.04794	.04886	.02192	.03312

[a] Corresponds to numbering under "Selection of Input Groups" above.

[b] O and L correspond, respectively, to the use of original and logarithmic data.

[c] Data were not available for these periods.

Current magnitudes of individual production elasticity estimates may be somewhat misleading due to the fact that they are averages for a ten-year period. For example, if the productivity of fertilizer is increasing, the 1961 value would be greater than .043; likewise, the estimate for labor would be less than .290.

Table V includes the average factor share for comparison with the production elasticity estimates. Fertilizer and lime estimates coincide closely with their average factor shares, denoting a nearly optimum total use of this input. The adjustment rate (.598) from Table VI is high, indicating that only two years are required, on the average, to make 90 percent of any needed adjustment. This high rate of adjustment is not in line with expected results. One reason for over-estimation of g may be that farmers underestimate the equilibrium factor use. In that case, the high rate of adjustment estimated relates to a "pseudo"-equilibrium and not to the "true" equilibrium. Such an overestimation of the adjustment rate would bias the elasticity estimate downward (see discussion pertaining to equation 3, this chapter).

The greatest divergence of E_t^* from the average factor share for feed, seed, and livestock purchases was in 1932-41 when the average factor share was only 64 percent of the optimum. The low adjustment rate, indicating 19 years required for 90 percent adjustment, does not seem consistent with farmers' adoption of new breeds and varieties, but may be biased because of inclusion of the 1930's period when such expenditures were low.

Labor's adjustment rate of .86 (which was the highest of any estimated) seems reasonable as an estimate of adjustments in man-hours worked.

TABLE VI

ESTIMATED RATES OF ADJUSTMENT IN INPUT USE AND YEARS REQUIRED FOR 90 PERCENT OF ADJUSTMENT[a]

Input	Adjustment Rate	Years to 90 Percent
1. Fertilizer and lime	.598	1.92
2. Feed, seed, and livestock	.113	19.20
3. Labor	.860	1.17
4. Machinery	.755	1.64
5. Real estate	.396	4.57
6. Fuel, operation, and repairs of machinery	.231	8.77
7. Miscellaneous current operating expenses	.474	3.58
8. Interest on crop and livestock inventory	.391	4.64
9. Real estate taxes	.448	3.88

[a] The number of years (N) required for a specific proportion of adjustment (A), given the adjustment rate (g) is determined as follows. Adjustment uncompleted after one year is (1-g), and after N years is $(1-g)^N$. Therefore, the adjustment completed after N years is $1-(1-g)^N$. Specify the adjustment to be completed (90%) and solve for N:

$$1-(1-g)^N = A,$$

$$(1-g)^N = 1-A,$$

$$N \log (1-g) = \log (1-A),$$

$$\text{and } N = \frac{\log (1-A)}{\log (1-g)} .$$

The man-hours series is used as the labor input in the production function developed later, but employment data would be expected to show a considerably lower rate of adjustment.

Adjustments in machinery use are rapid (g = .76). Comparison of production elasticity estimates and factor shares indicates an overinvestment in machinery in 1932-41 and 1952-61, with 1942-51 investment less than the optimum estimate.

Real estate expenses show an adjustment rate of .396, indicating approximately 4.5 years are required for a 90 percent adjustment. Factor share and elasticity comparisons show greater than optimum expenditures on real estate in 1932-41 and slightly lower than optimum expenditures in 1952-61.

The fuel and operating expense adjustment rate of .231 is less than a third of the adjustment rate for machinery investment, suggesting that farmers prefer increased capacity machinery to more intensive use of less efficient or smaller-sized machines. This may also reflect a lack of sufficiently skilled hired machine operators to perform timely operations with smaller, slower machines and equipment. Or it may arise because machinery operating expenses are adjusted only after machinery inventories are adjusted.

Adjustments in miscellaneous operating expenses are fairly rapid ($g = .474$) and factor share and elasticity estimates compare closely. Adjustment rates in the interest on crop and livestock inventories and real estate tax groups are .391 and .448, respectively, and show fairly rapid adjustment. The real estate tax input is an attempt to measure the productivity of a "social input". Comparing E_t^* and the average factor share would indicate that benefits were less than taxes in 1932-41, but have slightly exceeded taxes in the last period.

Specification of an Aggregate Production Function

The production elasticities estimated in the preceding section provide the basis for specifying input-output relationships in the form of an aggregate production function. Such a function can then be incorporated into an economic model relating agriculture and the nonfarm sector, or it can be used independently to determine optimum combinations of inputs for specified outputs under <u>ceteris paribus</u> conditions.

If it is hypothesized that the imputed elasticities of production express input-output relationships in a Cobb-Douglas type function such as

$$Y = aX_1^{b_1}X_2^{b_2}\ldots X_9^{b_9}\ , \tag{15}$$

then the only value remaining to be estimated is <u>a</u>. This function is selected because of its frequency of occurrence in production economics literature and its relative simplicity of use, because the b_i estimates are already available, and because the Cobb-Douglas function is expected to have good predictive ability within the range of data used.

The a-value may be determined in two alternative ways, depending on whether the error term for equation (15) is assumed to be additive or multiplicative. If the additive assumption is used, then $\prod_1^9 X_i^{b_i}$ can be written as one variable Z. The a-value is estimated from the linear relation

$$Y = aZ + e, \tag{16}$$

using least squares. Data for Y and the X's are in constant dollars, and raw sums of squares and cross-products are used to eliminate the usual intercept term. That is, $\hat{a} = \sum YZ/\sum Z^2$.

In the multiplicative error-assumption case the function becomes

$$Y = aZe, \tag{17}$$

and <u>a</u> is estimated from

$$\log Y = \log a + \log Z + \log e \tag{18}$$

as: $$\hat{a} = \text{antilog } [1/n\ (\sum \log Y - \sum \log Z)].$$

Selection of the proper assumption can be made by comparing the results and selecting the method which leaves the least unexplained residual; i.e., select the equation giving the higher R^2. Using this criterion the additive case (equation 16) was the better assumption, though the difference was slight, and comparison of the $\hat{a}$'s estimated both ways showed differences of less than seven percent. The $\hat{a}$'s obtained based on equation 16 were:

1932-41: 7.64468

1942-51: 17.55649[19]

1952-61: 7.52389

Incorporating these estimates with the production elasticity estimates from Table V in the preceding section provides a separate production function for three ten-year periods:

$$1932\text{-}41: \quad Y = 7.64468 \prod_{1}^{9} X_i^{\,b_i}$$

$$1942\text{-}51: \quad Y = 17.56649 \prod_{1}^{9} X_i^{\,b_i}$$

$$1952\text{-}61: \quad Y = 7.52389 \prod_{1}^{9} X_i^{\,b_i}$$

This set of production functions forms the basis of the simulation model, as the medium of transforming behavioral relations associated with input use into output, price, and income estimates, which in turn form the criteria for the succeeding year's production decisions.

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[19] The large intercept term for 1942-51 is primarily due to the low productivity estimate obtained for real estate during the war and postwar period (see Table V).

CHAPTER IV

ESTIMATION OF COEFFICIENTS FOR THE SIMULATION MODEL

The simulation model was described briefly in terms of a programming flow diagram in Chapter II. A detailed description of the model and explanation of the estimated coefficients will be given in this chapter.

For convenience, the simulation model will be discussed as though it were composed of three phases; (1) pre-input, (2) input, and (3) output. The first phase is termed pre-input because estimated values of certain variables are used as behaviorial criteria in determining the level of input use in the succeeding phase. The second, or input, phase determines the level of use of each of the nine input categories involved in the production function. The output phase includes the production function for each ten-year period, and the aggregate demand and gross farm income equations. These equations complete the model for year t, and estimates of output, prices received, and income enter the iteration for year t + 1, influencing production decisions for the coming year.

"Pre-Input" Behavioral Equations

Theoretical Relations

The demand for inputs is strongly influenced by cuttent and past values of selected decision variables. Past values are essential for the formulation of expected values for the current period, since at the beginning of the production year such variables are prices received, income from the production just starting, purchases, and average stocks cannot be known. Decisions must be made, however, and the best guide usually available is knowledge of events and conditions of the previous period, which provide the basis for the formation of expectations.

Variables for which expected values are required at this stage are (1) the number of acres of cropland to be used for crops in the current year, (2) the average inventory of crops and livestock for the period, (3) purchases of machinery and average stock of machinery, (4) the price of real estate, and (5) the value of real estate (from which taxes are computed). These expected values are derived from a set of equations and identities described below, where the dependent variables are as follows:

AC_t = acreage of cropland to be used for crops in the current year,

CLI_{t+1} = crop and livestock inventory at the end of the current year (i.e., beginning of next year)

SP_{t+1} = stock of productive assets at the end of the current year,

PUR_t = purchases of machinery during the current year,

SM_{t+1} = stock of machinery at the end of the current year,

PRE_t = price of real estate during the current year,

VRE_t = total value of real estate for the current year,

$CLIM_t$, SPM_t, SMM_t = average levels, defined as equal to one-half of beginning plus ending inventories

Independent variables included are those which are hypothesized to have the greatest ability to explain the level of the dependent variables involved. Equations are presented in implicit form below, with description of the independent variables and discussion of the implicit relationships following. The equations in implicit form are:

(1.0) $$AC_t = f(AC_{t-1}, SP_t, PF_{t-1}, PR_{t-1})$$

(2.0) $$AC_t = f(AC_{t-1}, SP_t, PF_{t-1}, PR_{t-1}, ADIV_t)$$

(3.0) $$CLI_{t+1} = f(CLI_t, GFI_{t-1}, OUT_{t-1})$$

(4.0) $$SP_{t+1} = f(SP_t, GFI_{t-1})$$

(5.0) $$PUR_t = f(GFI_{t-1})$$

(6.0) $$SM_{t+1} = f(PUR_t, SM_t)$$

(7.0) $$PRE_t = f(PRE_{t-1}, GFI_{t-1})$$

(8.0) $$VRE_t = f(PRE_t)$$

Identities are:

$$CLIM_t = (CLI_{t+1} + CLI_t)\ (.5)$$

$$SPM_t = (SP_{t+1} + SP_t)\ (.5)$$

$$SMM_t = (SM_{t+1} + SM_t)\ (.5)$$

Independent (explanatory) variables that are not lagged values of previously described dependent variables are:

ADIV = acres diverted from production by government programs

PF = index of prices paid by farmers for fertilizer materials

PR = index of prices received by farmers

GFI = gross farm income

OUT = value of farm output

Acres diverted are in millions. Price indexes are based on 1947-49=100 and are deflated by the implicit price deflator of the gross national product. Gross income and the value of farm output are in million 1947-49 dollars. Data used are for 1929-60 and are described in Appendix A, Table III.

Least Squares Estimates

All equations were estimated in linear form using least squares regression techniques. Results obtained are presented in this section. The objective of the simulation model is to provide a quantitative representation of structural relations in U. S. agriculture. Economic relations given by the equations are, therefore, expected to show causal relationships, except as it was felt necessary to compromise in favor of timesaving and manipulative ease. References to "explanation" are in terms of predictive ability of the equation and do not necessarily mean that causative economic relations are explained. Since the least squares' assumption of independence between the error term and the explanatory variables is not met in some cases (e.g., where the lagged value of the dependent variable is included as an "independent" variable) the interpretation of coefficients as structural rather than predictive is not always appropriate.[1]

Acres of cropland. The decision of how much cropland to allocate to production in year t is hypothesized to depend strongly on last years' allocation. Additional influencing factors are the total stock of productive assets available, the cost of plant nutrients, the level of prices received, and government programs for limiting cropland acreage. The estimated relation between cropland acres and the explanatory variables prior to the beginning of effective acreage control programs in 1956 is (1.1):

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[1] Cf. J. Johnston, pp. 211-221 and Chapter 6, for a discussion of "Lagged Variables" and "Errors in Variables".

$$(1.1)\quad \hat{AC}_t = 87.57229 + \underset{(4.9)^{**}}{.64625AC_{t-1}} + \underset{(.32)}{.00003SP_t} + \underset{(1.73)}{.20668PF_{t-1}}$$

$$+ \underset{(3.11)^{**}}{.23255PR_{t-1}} \qquad R^2 = .760$$

Figures in parentheses beneath the estimated coefficients are calculated t-values. Two asterisks (**) indicate significance at the one percent probability level; one asterisk (*) the five percent level. The coefficient of determination (R^2) indicates that 76 percent of the variability in the AC_t series is "explained" by the variables included in the equation.

An alternative equation for estimating AC_t after 1955 is (2.1), below. The acreage diversion variable is added to account for net reduction in planted acreage due to government programs. Programs included are the Conservation Reserve, Cropland Conversion, Feed Grains, and Wheat programs. The acreage allotment programs of the 1950's are not included since they were not effective in reducing total production.[2] This alternative equation (based on 1956-64 data) is:

$$(2.1)\quad \hat{AC}_t = -161.30628 - \underset{(-4.67)^{*}}{.092273\ ADIV_t} + \underset{(0.84)}{.07881\ AC_{t-1}}$$

$$+ \underset{(3.06)}{.02204SP_t} + \underset{(2.43)}{2.67889PF_{t-1}} + \underset{(.01)}{.0069\ PR_{t-1}} \qquad R^2 = .996$$

Ability to predict AC_t is high (i.e., $R^2 = .996$), but due to the limited number of degrees of freedom only one coefficient is significant at the five percent level. The coefficients of SP_t and PF_{t-1} are significant at the ten percent level.

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[2] Cf. U. S. Department of Agriculture, Effects of Acreage Allotment Programs, Production Research Report No. 3, Agricultural Research Service, June 1956.

Crop and livestock inventory. The expected value of the year's ending crop and livestock inventory is influenced by the beginning inventory, the previous year's output[3], and last year's income--which determines the likelihood of depleting or increasing inventories in year t. The estimated equation is:

$$\hat{CLI}_{t+1} = 5421.775 + \underset{(1.38)}{.35045}\,CLI_t - \underset{(-.56)}{.02922}GFI_{t-1} + \underset{(2.17)^{*}}{.34221}OUT_{t-1} \qquad R^2 = .816 \tag{3.1}$$

The only coefficient significant at a high level of probability is that of lagged output, with the coefficient of beginning inventory significant at the 20 percent level. Despite the lack of statistical significance in individual coefficients, the independent variables account for 82 percent of the variation in the dependent series.

Stock of productive assets. The stock of productive assets at the end of year t depends on the beginning stock, and also on last year's income, which should influence farmers' decisions to reduce or add to their productive capacity. The estimated equation is (4.1),

$$\hat{SP}_{t+1} = -2552.222 + \underset{(2.99)^{**}}{.30869}GFI_{t-1} + \underset{(22.76)^{**}}{.96046}SP_t \qquad R^2 = .973 \tag{4.1}$$

with coefficients of beginning stock and income highly significant.

Machinery purchases. Purchases of machinery were hypothesized to depend on beginning machinery stock, purchases last year, price of machinery last year, and gross farm income in the preceding year. The first

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[3] Actually, OUT_{t-1} is a proxy variable for OUT_t, which is not yet determined.

equation estimated using these variables and data for 1929-60 did not predict as well as expected. Consequently the data were divided into two sets depending on whether $GFI_{t-1} \gtrless GFI_{t-2}$ in order to isolate the effects of asset fixity under increasing and decreasing incomes. For the two equation formulation GFI_{t-1} was used as the sole independent variable. Equation (5.1) is based on data for 17 years in which $GFI_{t-1} > GFI_{t-2}$ (increasing income):

$$(5.1) \qquad \hat{PUR}_t = -529.777 + \underset{(5.46)^{**}}{.08058}\, GFI_{t-1} \qquad R^2 = .665$$

Equation (5.2) is the result of using the remaining 14 years of data where income was decreasing ($GFI_{t-1} < GFI_{t-2}$):

$$(5.2) \qquad \hat{PUR}_t = -1320.563 + \underset{(18.79)^{**}}{.10708}\, GFI_{t-1} \qquad R^2 = .967$$

Decreasing income has a more pronounced effect on machinery purchases (as indicated by equation 5.2) than the income variable in periods of increasing income. Prediction in the simulation model was considerably enhanced by using the two equations above in lieu of the single equation with data for all years.

Stock of machinery. The ending stock of machinery is estimated using the beginning stock and current year purchases as explanatory variables. The estimated equation is (6.1),

$$(6.1) \qquad \hat{SM}_{t+1} = -175.08368 + \underset{(12.63)^{**}}{.8426}\, PUR_t + \underset{(53.72)^{**}}{.86576}\, SM_t \qquad R^2 = .996$$

giving highly significant coefficients.

Real estate price and value. Factors affecting real estate price are many, but it was thought that the preceding year's price and income being earned from farming should provide adequate explanation. The estimated equation is (7.1),

$$(7.1) \quad \hat{PRE}_t = -5.31360 + \underset{(3.61)^{**}}{.00042GFI_{t-1}} + \underset{(17.05)^{**}}{.95482PRE_{t-1}} \qquad R^2 = .936$$

with highly significant coefficients.

Total real estate value in the model depends primarily on the price level since the volume is subject to little variation. Estimating value as a function of price gave equation (8.1),

$$(8.1) \quad \hat{VRE}_t = -3253.315 + \underset{(69.75)^{**}}{754.84551PRE_t}, \qquad R^2 = .994$$

with a highly significant coefficient and a high R^2.

Input Equations

The purpose of the input section of the economic model is to provide estimates of current-year inputs for each input category for given levels of the explanatory variables. Estimates of input levels will then be used in the production functions in the "output" section.

The input variables in the production function have been presented in Chapter III, and are described in Appendix A, Table III. To facilitate further reference the inputs are given symbolic abbreviations below:

FL = expenditures for fertilizer and lime
FSL = feed, seed, and livestock purchases
TFLF = total farm labor force
XLT = total labor man-hours
XM = machinery expense

RE = real estate expense

FOE = fuel, operation, and repairs of machinery expense

XMIS = miscellaneous current operating expense

XINT = interest on crop and livestock inventories

RET = real estate taxes

Theoretical Relations

Input demand equations in implicit form are as follows:

$$\hat{FL}_t = f(GFI_{t-1}, PF_{t-1}, FL_{t-1}) \tag{9.0}$$

$$\hat{FSL}_t = f(CLIM_t, FSL_{t-1}) \tag{10.0}$$

$$\hat{TFLF}_t = f(SMM_t, U_{t-1}, PNF_{t-1}) \tag{11.0}$$

$$\hat{XLT}_t = f(TFLF_t) \tag{12.0}$$

$$\hat{XM}_t = f(SMM_t) \tag{13.0}$$

$$\hat{RE}_t = f(VRE_t, T) \tag{14.0}$$

$$\hat{FOE}_t = f(SMM_t, AC_t, PMS_{t-1}) \tag{15.0}$$

$$\hat{XMIS}_t = f(SPM_t, PFS_{t-1}) \tag{16.0}$$

$$\hat{XINT}_t = f(CLIM_t) \tag{17.0}$$

$$\hat{RET}_t = f(VRE_t, TAX_t) \tag{18.0}$$

where previously unexplained variables are:

U = unemployment,

PNF = nonfarm labor-wage rate,

T = trend variable (year),

PMS = index of prices paid for motor supplies,

PFS = index of prices paid for farm supplies,

TAX = real estate tax rate.

Fertilizer and lime. Expenses for fertilizer and lime (9.0) were expected to be explainable by the estimated acreage of cropland allocated to crop production in year t and gross income in the preceding year. Nonfarm purchases of feed, seed, and livestock (10.0) are expressed simply as dependent on the average inventory of crops and livestock.

Labor. The total farm labor force (equation 11.0) is specified as a function of the average stock of machinery (SMM_t), unemployment (U_{t-1}), and the nonfarm wage rate (PNF_{t-1}). The number of man-hours worked by farm labor (XLT_t, the variable employed in the production function) is determined from the total farm labor force in equation (12.0).

Machinery ownership and operating expenses. Miscellaneous current operating expense (16.0) was expressed as dependent on the average stock of assets and the price of farm supplies. Interest on crop and livestock inventory (17.0) was specified as dependent on the average crop and livestock inventory.

Real estate expense and taxes. The remaining two equations relate real estate expense (14.0) to the value of real estate and a trend variable, with real estate taxes (19.0) determined by the tax rate and the estimated value of real estate.

Estimated Equations

Estimation of the coefficients for the input demand equations resulted in the following linear relations:

(9.1) $$\hat{FL}_t = 584.5834 - \underset{(-2.33)^{*}}{4.11854PF_{t-1}} - \underset{(-.22)}{.00048GFI_{t-1}}$$

$$+ \underset{(15.86)^{**}}{.88698FL_{t-1}} \qquad R^2 = .992$$

(10.1) $$\hat{FSL}_t = -66.442 + \underset{(2.42)^{*}}{.04534CLIM_t} + \underset{(14.26)^{**}}{.88516FSL_{t-1}} \qquad R^2 = .984$$

(11.1) $$\hat{TFLF}_t = 11618.758 - \underset{(-10.28)^{**}}{.41963SMM_t} - \underset{(-2.64^{*})}{8.2967}(1-5U_{t-1})\ (PNF_{t-1})$$

$$R^2 = .923$$

(12.1) $$\hat{XLT}_t = -4544.288 + \underset{(29.16)^{**}}{2.65069TFLF_t} \qquad R^2 = .967$$

(13.1) $$\hat{XM}_t = 121.47680 + \underset{(99.92)^{**}}{.23987SMM_t} \qquad R^2 = .997$$

(14.1) $$\hat{RE}_t = -22556.27 + \underset{(5.61)^{**}}{13.22438T} + \underset{(2.74)^{*}}{.00474VRE_t} \qquad R^2 = .844$$

(15.1) $$\hat{FOE}_t = 7732.539 - \underset{(-4.80)^{**}}{10.17682\ AC_t} + \underset{(11.28)^{**}}{.11792SMM_t}$$

$$- \underset{(-14.26)^{**}}{27.6532PMS_{t-1}} \qquad R^2 = .986$$

(16.1) $$\hat{XMIS}_t = 1273.4703 + \underset{(10.37)^{**}}{.01771SPM_t} - \underset{(-3.68)^{**}}{15.6162PFS_{t-1}} \qquad R^2 = .962$$

(17.1) $$\hat{XINT}_t = 4.4849 + \underset{(21.44)^{**}}{.06153CLIM_t} \qquad R^2 = .941$$

Real estate taxes are defined as the product of the tax rate and the estimated value of real estate:

(18.1) $$\hat{RET}_t = (TAX_t)\ (VRE_t)$$

Explanation was lowest for the real estate equation, which had an R^2 of .84. However, the real estate equation gave adequate prediction in the model, which in this case was more desirable than an excellent statistical fit of the individual equation.

Aggregate Output, Demand and Gross Income Equations

This section completes the system, and includes (1) a production function for each of three periods (1930-41, 1942-51, and 1952-60) of the form:

$$(19.0) \qquad \hat{OUT}_t = aFL_t^{b_1} \, FSL_t^{b_2} \, \ldots \, RET_t^{b_9} ,$$

(2) an identity for the portion of output entering the commercial market, (3) a behavioral demand equation (at the farm level), and (4) a gross farm income equation.

Aggregate Output

The production functions are:

$$(19.1) \qquad \hat{OUT}_t \ (1930\text{-}41) = 7\ 64468(FL_t)^{.02648} (FSL_t)^{.06165} (XLT_t)^{.34777} (XM_t)^{.06056} (RE_t)^{.23619} (FOE_t)^{.06513} (XMIS_t)^{.07550} (XINT_t)^{.04587} (RET_t)^{.03861}$$

$$(19.2) \qquad \hat{OUT}_t \ (1942\text{-}51) = 17.56649(FL_t)^{.02885} (FSL_t)^{.08766} (XLT_t)^{.34458} (XM_t)^{.07768} (RE_t)^{.14837} (FOE_t)^{.06901} (XMIS_t)^{.05133} (XINT_t)^{.04441} (RET_t)^{.02112}$$

$$(19.3) \qquad \hat{OUT}_t \ (1952\text{-}60) = 7.52389(FL_t)^{.04325} (FSL_t)^{.08862} (XLT_t)^{.28983} (XM_t)^{.09408} (RE_t)^{.23816} (FOE_t)^{.10321} (XMIS_t)^{.07793} (XINT_t)^{.04112} (RET_t)^{.03542}$$

Input data for the production functions are determined annually in the "input" section and the coefficients b_i are from Chapter III.

Commercial marketings. All of each year's farm output does not enter the market during that year or does not necessarily enter the commercial market at all. Possible dispositions other than sales in the commercial market are consumption on farms where produced, addition to inventories on farms, or diversions by the government through Commodity Credit Corporation. Consequently, an identity is set up to define the commercial market quantity (CMQ) as the residual of output minus dispositions. The identity is:

$$CMQ_t = OUT_t - HC_t - CIF_t - GD, \qquad (20.0)$$

where

HC = home consumption,

CIF = change in inventories on farms, and

GD = government diversions.

Aggregate Demand

A "structural" aggregate demand equation was synthesized based on estimates in the literature of demand, income, and other-price elasticities. Variables included in the initial synthesized equation are PR, CMQ, YD, CPI, and POP. Coefficients were selected for quantity (CMQ), income (YD) and other prices (CPI) to provide elasticities of relevant magnitudes.[4] Thus the partially formulated equation is (21.0):

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[4] Coefficients selected provide elasticities as follows: εD_p (own price) = $-.30$; εD_Y (income) = $.25$; and $\varepsilon D_p'$ (other prices) = $.05$.

$$(21.0)\qquad PR_t = -.01121\ CMQ_t + .05298 YD_t + .14582\ CPI_t + U,$$

where U is the unexplained portion of PR. To complete the equation, U is regressed on population (POP) and a dummy variable (D) equal to 1 for the years 1942-47, zero elsewhere, by autoregressive least squares to obtain equation (21.0) (with PR again expressed as the dependent variable):[5]

$$\begin{aligned}(21.1)\qquad \hat{PR}_t = {} & -44.29011 - .01121\ CMQ_t + .05298\ YD_t + .14582\ CPI_t \\ & +.40326[PR_{t-1} + .01121\ CMQ_{t-1} - .05298\ YD_{t-1} - .14582 \\ & CPI_{t-1} - 2.2944249\ POP_{t-1}] + 2.2944249\ POP_t + 24.18D_t\end{aligned}$$

Calculated t-values for the autocorrelation coefficient $\beta = .40326$, and the coefficient of POP_t are 14.85 and 55.53.

Gross Farm Income

Gross farm income is the final quantity estimated in the model and is determined as a function of the quantity of commercial marketings (CMQ), the level of prices received by farmers (PR), and government payments to farmers (GP):

$$GFI_t = f(CMQ_t, PR_t, GP_t)$$

Estimation of the coefficients by least squares for this equation resulted in equation (22.0):

$$(22.0)\qquad \hat{GFI}_t = 1805.5666 + \underset{(0.64)}{.35663}\ GP_t + \underset{(32.16)^{**}}{1.30360}\ (PR_t/100)\ (CMQ_t)$$

$$R^2 = .973$$

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[5] Other sets of dummy variables used in lieu of D gave higher R^2's but poorer prediction in the model.

Summary of the Model

A quantitative description of the activity of the agricultural sector and the interaction of this activity with the nonfarm sector is the intent of this model. Interaction with the nonfarm sector is most readily observable through the demand for farm products, unemployment level, government payments to farmers, government diversion of cropland, government diversions of production, and prices received by farmers. The model assumes that supplies of items used by farmers in production and purchased from the nonfarm sector are available in any quantity at the prevailing price, i.e., the supply of nonfarm produced inputs is perfectly elastic. With this assumption in mind, the entire model is recursive, with estimated values of certain variables in year t used in decision-making for t + 1.

This section brings together the component parts of the empirical model and explains the operation of the simulation procedure in greater deatil. An exclusively verbal explanation of the operation is difficult, therefore Figure 5 is used to supplement the verbal explanation. The FORTRAN source statement program, included as Appendix B, also aids in understanding the working of the model.

Figure 5 shows the operation of the simulation model for one year (1930). Variables which have an asterisk(*) above them are actual values read into the computer initially. A plus sign (+) above the variable name indicates that actual data were used for 1929, with data for later years being simulation estimates from the preceding year. A short arrow (↓) above a variable indicates that the numerical value is calculated earlier in the same iteration.

PRE-INPUT

$$\mathrm{AC}_{30} = f(\overset{\dagger}{\mathrm{AC}}_{29}, \overset{*}{\mathrm{SP}}_{30}, \overset{*}{\mathrm{PF}}_{29}, \overset{\dagger}{\mathrm{PR}}_{29})$$

$$\mathrm{CLI}_{31} = f(\underset{\downarrow}{\overset{\dagger}{\mathrm{OUT}}}_{29}, \overset{\dagger}{\mathrm{GFI}}_{29}, \overset{*}{\mathrm{CLI}}_{30})$$

$$\mathrm{CLIM}_{30} = (\mathrm{CLI}_{31} + \overset{*}{\mathrm{CLI}}_{30})\ (.5)$$

$$\mathrm{SP}_{31} = f(\underset{\downarrow}{\overset{\dagger}{\mathrm{GFI}}}_{29}, \overset{*}{\mathrm{SP}}_{30})$$

$$\mathrm{SPM}_{30} = (\mathrm{SP}_{31} + \overset{*}{\mathrm{SP}}_{30})\ (.5)$$

$$\mathrm{PUR}_{30} = f(\overset{\dagger}{\mathrm{GFI}}_{29})$$

$$\mathrm{PRE}_{30} = f(\underset{\downarrow}{\overset{\dagger}{\mathrm{PRE}}}_{29}, \overset{\dagger}{\mathrm{GFI}}_{29})$$

$$\mathrm{SM}_{31} = f(\underset{\downarrow}{\mathrm{PUR}}_{30}, \overset{*}{\mathrm{SM}}_{30})$$

$$\mathrm{SMM}_{30} = (\mathrm{SM}_{\underset{\downarrow}{31}} + \overset{*}{\mathrm{SM}}_{30})\ (.5)$$

$$\mathrm{VRE}_{30} = f(\mathrm{PRE}_{30})$$

INPUT

$$\mathrm{FL}_{30} = f(\underset{\downarrow}{\overset{*}{\mathrm{PF}}}_{29}, \overset{\dagger}{\mathrm{GFI}}_{29})$$

$$\mathrm{FSL}_{30} = f(\underset{\downarrow}{\mathrm{CLIM}}_{30}, \overset{\dagger}{\mathrm{FSL}}_{29})$$

$$\mathrm{TFLF}_{30} = f(\underset{\downarrow}{\mathrm{SMM}}_{30}, \overset{*}{\mathrm{U}}_{30}, \overset{*}{\mathrm{PNF}}_{30})$$

$$\mathrm{XLT}_{30} = f(\underset{\downarrow}{\mathrm{TFLF}}_{30})$$

$$\mathrm{XM}_{30} = f(\underset{\downarrow}{\mathrm{SMM}}_{30})$$

$$\mathrm{RE}_{30} = f(\underset{\downarrow}{\mathrm{VRE}}_{30}, \overset{*}{\mathrm{T}}_{30})$$

$$\mathrm{FOE}_{30} = f(\underset{\downarrow}{\mathrm{SMM}}_{30}, \overset{*}{\mathrm{PMS}}_{29})$$

$$\mathrm{XMIS}_{30} = f(\underset{\downarrow}{\mathrm{SPM}}_{30}, \overset{*}{\mathrm{PFS}}_{29})$$

$$\mathrm{XINT}_{30} = f(\underset{\downarrow}{\mathrm{CLIM}}_{30})$$

$$\mathrm{RET}_{30} = f(\mathrm{VRE}_{30}, \overset{*}{\mathrm{TAX}}_{30})$$

OUTPUT

$$\mathrm{OUT}_{30} = \underset{\downarrow}{f}(\overset{\downarrow}{\mathrm{INPUTS}}_{30})$$

$$\mathrm{CMQ}_{30} = \mathrm{OUT}_{\underset{\downarrow}{30}} - \overset{*}{\mathrm{HC}}_{30} - \overset{*}{\mathrm{CIF}}_{30} - \overset{*}{\mathrm{GD}}_{30}$$

$$\mathrm{PR}_{30} = f(\mathrm{CMQ}_{30}, \underset{\downarrow}{\overset{*}{\mathrm{POP}}}_{30}, \underset{\downarrow}{\overset{*}{\mathrm{YD}}}_{30}, \overset{*}{\mathrm{CPI}}_{30})$$

$$\mathrm{GFI}_{30} = f(\overset{*}{\mathrm{GP}}_{30}, \mathrm{CMQ}_{30}, \mathrm{PR}_{30})$$

Figure 5. Schematic Diagram Showing Operation of the Simulation Model for One Year (1930) (See text for explanation of symbols above variable names).

The first complete iteration begins with the estimation of AC_{30} and ends with the estimation of GFI_{30}. Estimated values from this iteration for variables indicated (+) are used in conjunction with actual data and the given coefficients to estimate AC_{31}, CLI_{31}, etc.

Feedback variables (indicated by +) are included to adapt the model for simulation analysis. That is estimated values for the preceding year must be incorporated into the decision framework for year t if the model is to be used as an analytical device.

The basis for acceptance of the final model is explained in the beginning of Chapter V, where testing of the original simulation model is explained.

CHAPTER V

SIMULATION ANALYSIS

Prior to using the simulation model for analysis of questions raised in Chapter I, a comparison of actual data series and the simulation estimates is in order to test the predictive ability of the original model. Following a discussion of simulation testing of the model is a brief summary of the general areas to be examined and the 15 simulations used in the analysis.

Simulation Testing of the Original Model

The sequence of model development involved (1) developing coefficients for the individual equations in the models, and (2) trial runs to determine how well estimates derived from the simulation procedure compared with actual data series. This comparison provides a logical test of the model, and is prerequisite to further analysis.

Revisions in the model were made by simulating the system over the period 1930-60 and comparing the estimated series with actual data, reformulating equations for variables whose estimates were unsatisfactory, and repeating the simulation. Equations presented earlier represent the final selections after trial runs of the simulation model.

The most critical estimates are those of variables which carry over from one iteration to the next. These variables are acres of cropland (AC); price of real estate (PRE); fertilizer and lime (FL); feed, seed, and livestock (FSL); output (OUT); prices received (PR); and gross farm income (GFI). Actual and estimated levels of these variables are graphed in Figure 6 as a visual indication of the degree of approximation achieved by the final simulation model.

In Figure 6(a) estimates of cropland acreage coincide closely with actual acreage from 1956-60. From 1930-55, the averages compare as follows: 376.3 for actual, 376.8 for estimated. The largest estimation error is in 1939 and amounts to only 4.2 percent.

Estimates of prices received are graphed in Figure 6(b). Averages for the 1930-60 period for actual values and estimates are 77.8 and 81.0, respectively. The greatest error was an overestimation of about 30 percent, occurring in 1940. Since 1942, however, the estimates are consistently close to actual values, with the exception of 1957 and 1958.

Figure 6(c) depicts actual and estimated real estate prices. Averages for actual prices and estimates, 1930-60, are 99.6 and 104.7, respectively, for an average overestimation of about five percent.

Actual and estimated output levels are compared in Figure 6(d). The largest estimation error since the mid-thirties is about 8.7 percent, occurring in 1941. Averages for the 1930-60 period compare as follows: $31,768.6 million for actual; $32,390.0 million for the estimate.

Gross farm income estimtes in Figure 6(e) reflect the compounded effects of errors in estimating the commercial market quantity (CMQ) and the price level (PR), since GFI equals PR times CMQ plus government payments (GP). The largest error is in the 1957 estimate which is 27 percent above the actual 1957 gross income figure. For the period as a

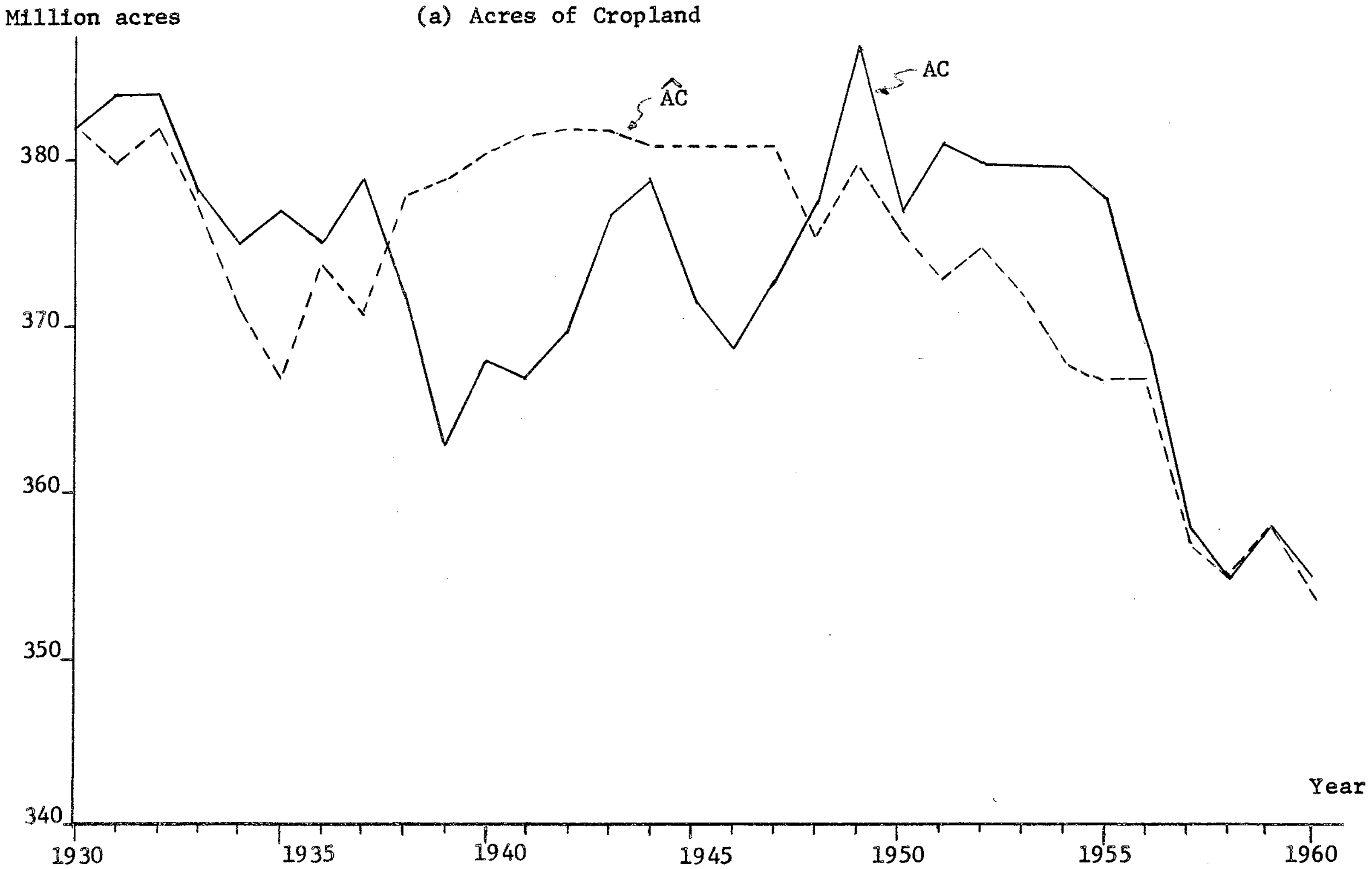

Figure 6. Comparison of actual values and simulation estimates for feedback variables, Model II.

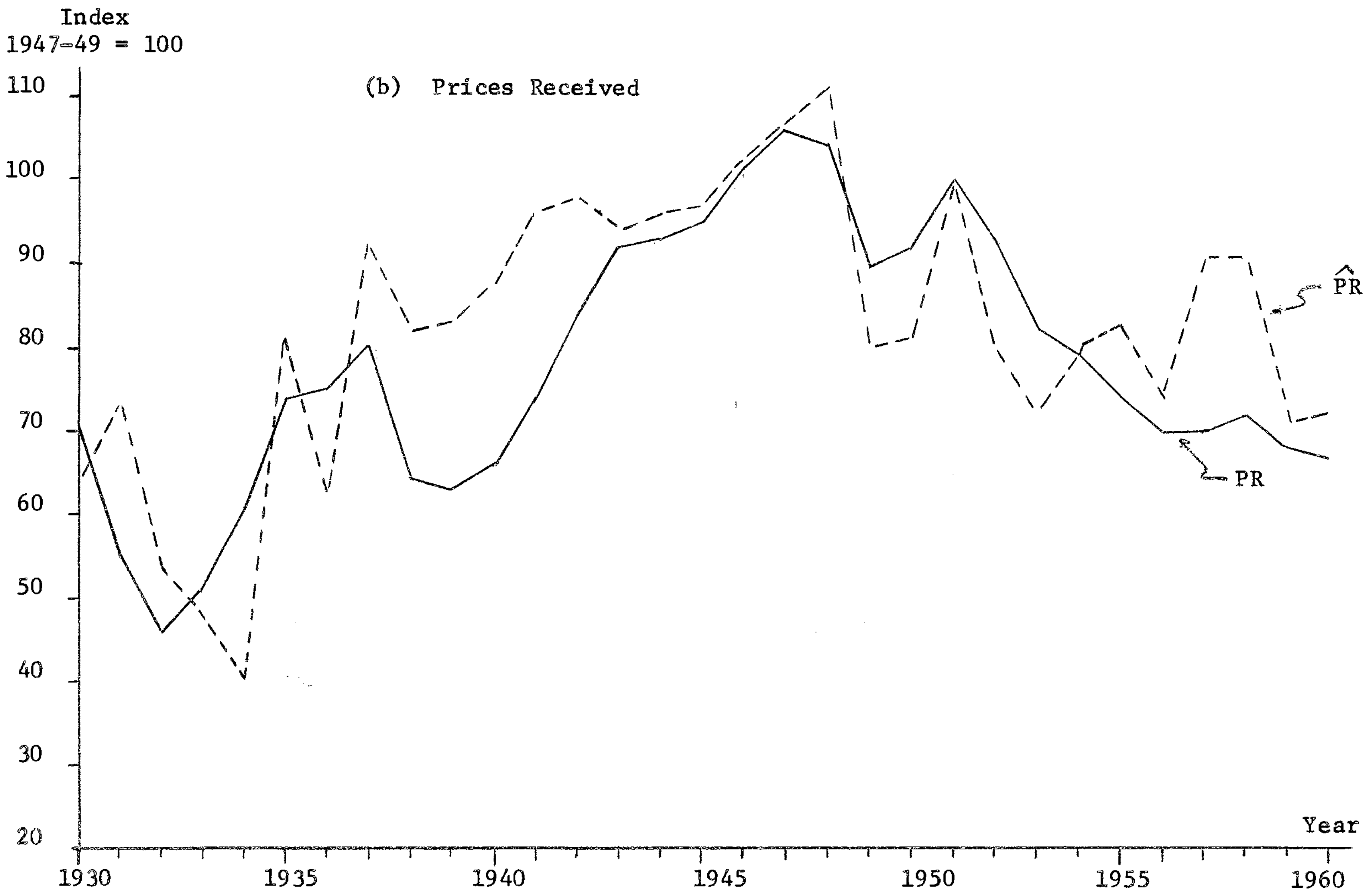

Figure 6. (Continued)

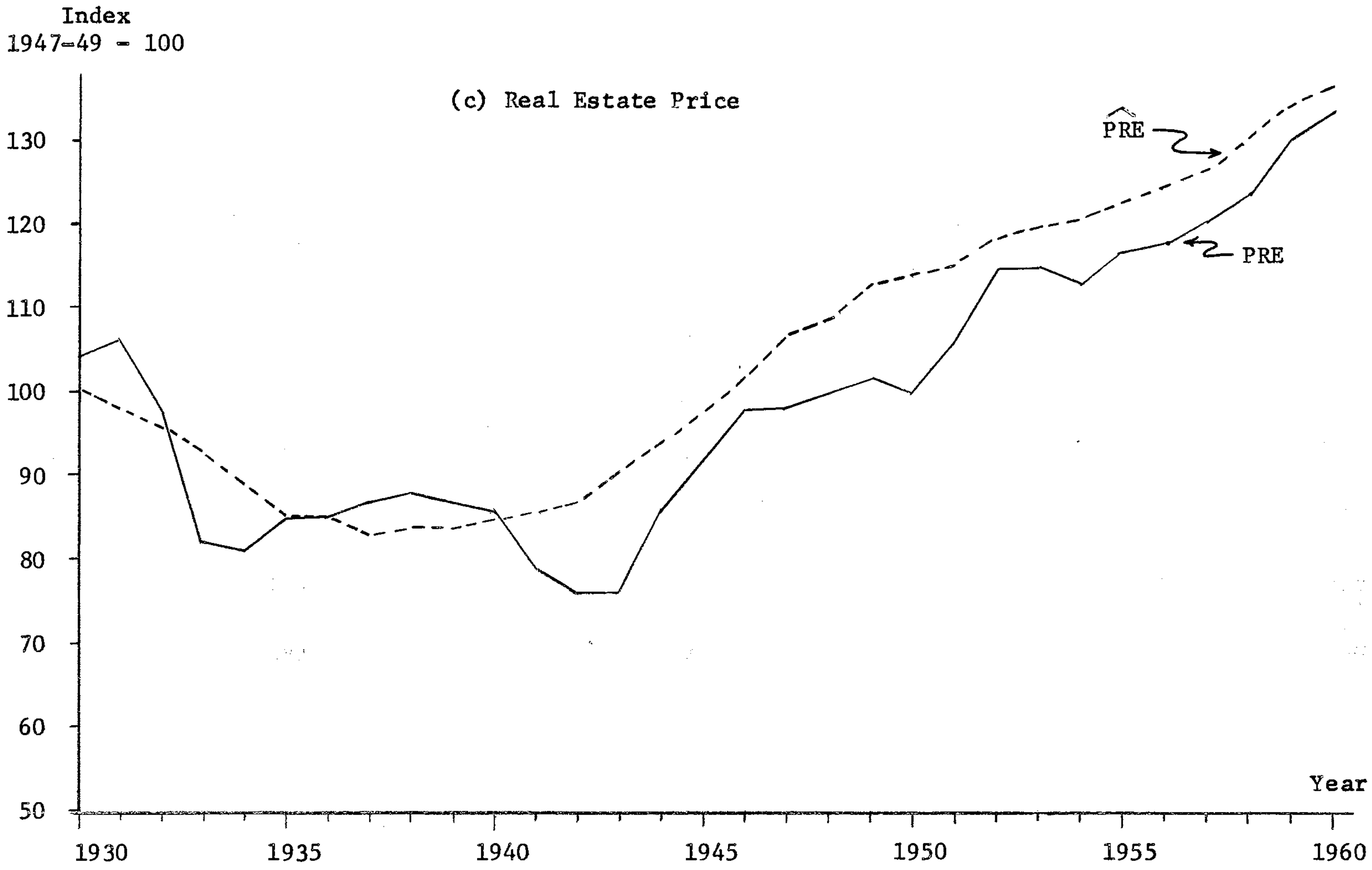

Figure 6. (Continued)

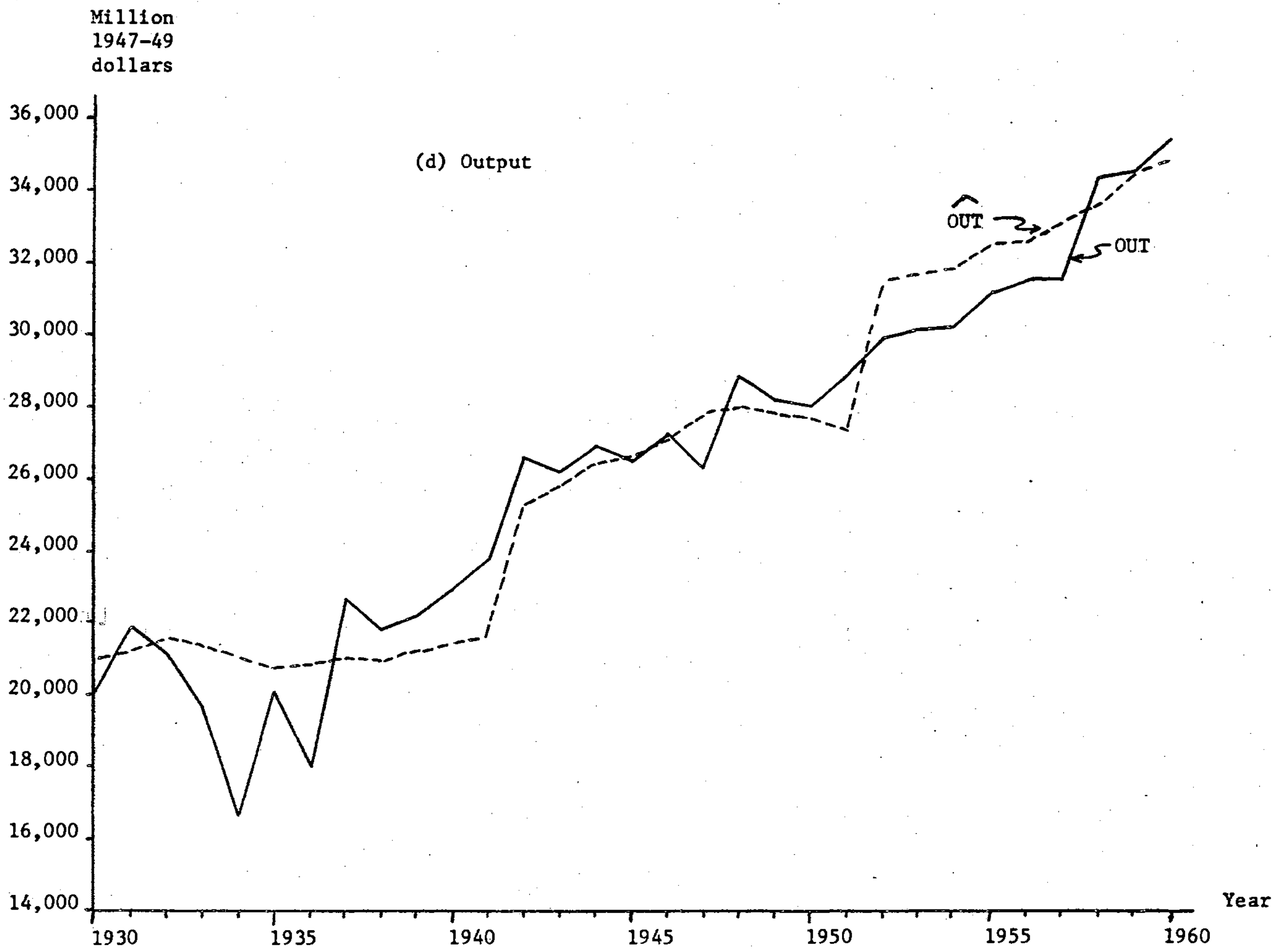
(d) Output

Figure 6. (Continued)

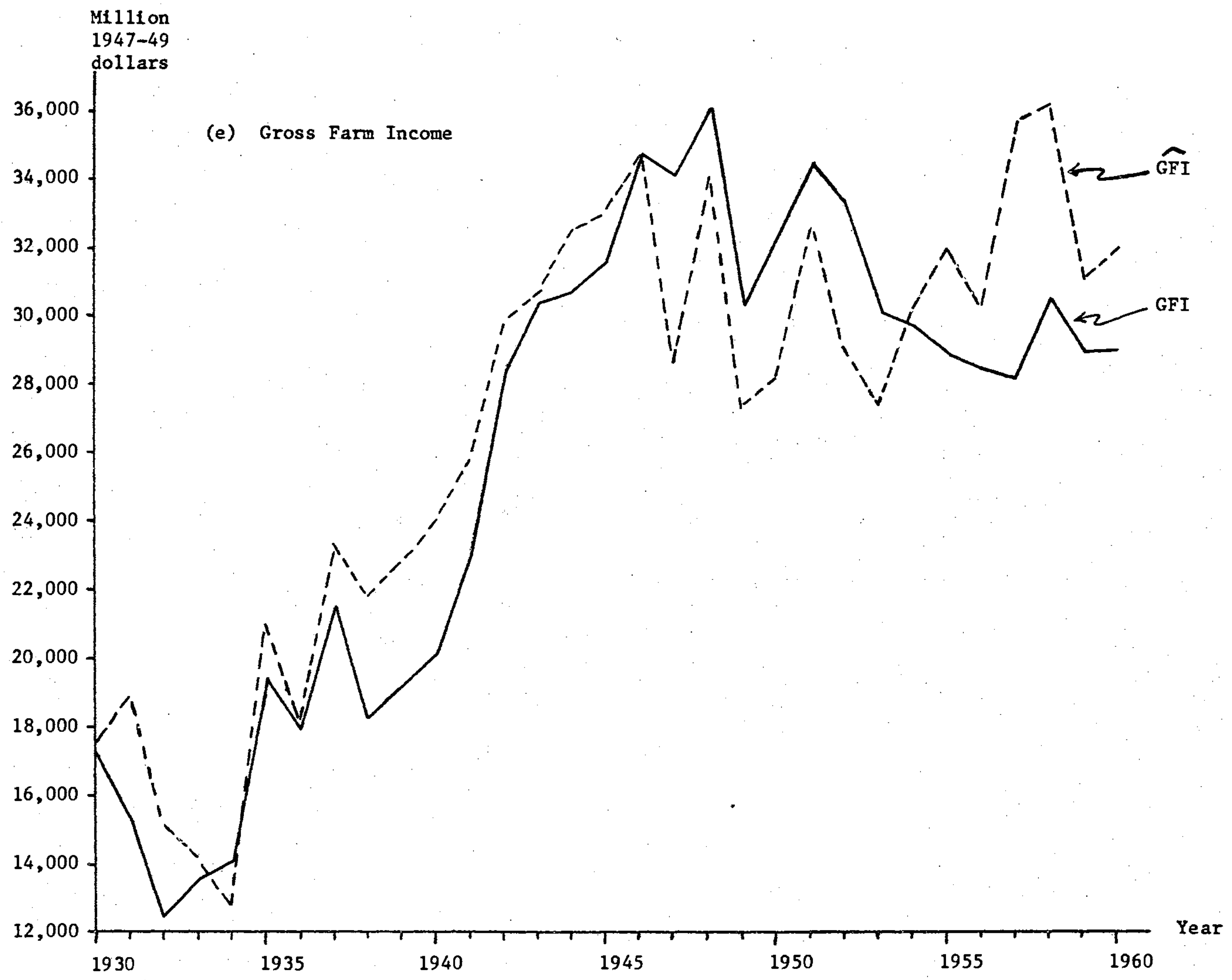
(e) Gross Farm Income

Figure 6. (Continued)

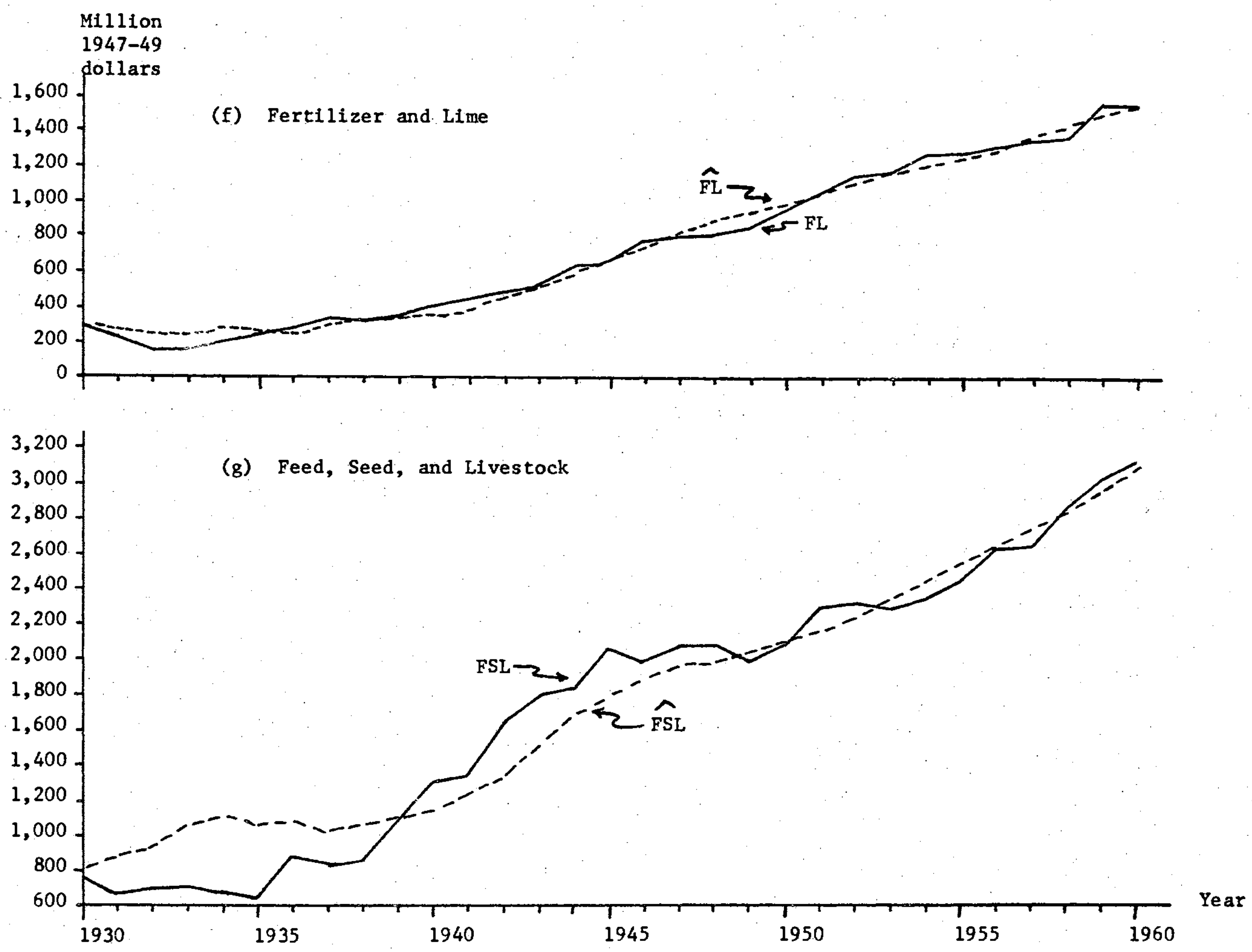

Figure 6. (Continued)

whole and for 1951-60, the estimates were in error by an average of four and nine percent, respectively.

The other feedback variables, FS and FSL, shown in Figures 6(f) and 6(g) appear to be predicted adequately by the simulation model. In summarizing the estimates depicted in Figure 6, two points should be emphasized. First, when selected variables are specified at other than actual levels, comparisons of predictions by the model will be made to the predicted values in the original simulation run rather than to actual data. Secondly, emphasis will be placed on averages of at least ten years to smooth out the fluctuations apparent in the annual estimates.

Results of Simulation Runs with Selected Changes in Data and Parameters

The preceding section has shown the operation of the simulation model under conditions prevailing over the period 1930-60. In essence, this reflects the ability of the model to "predict" what has already occurred.

What we desire to know, however, is what would have occurred under alternative conditions. Such knowledge can aid in a post-priori evaluation of agricultural policies. More importantly, such knowledge can aid in the development of policies for the future by indicating the effects of proposed changes in government programs and other variables upon farm income and resource use.

The purpose of this section is to present the results obtained for a selected set of alternative conditions, based on changes in certain variables and parameters. Three general areas are examined:

(a) the effect of government involvement in the farm economy,

(b) the impact of inflation and national economic conditions on the farm economy, and

(c) the economic implications for agriculture of alternate rates and forms of technological change.

Variables for which other than actual levels are to be assumed are (1) production removals by the Commodity Credit Corporation; (2) government payments to farmers; (3) government controls on acreage; (4) prices of inputs purchased from the nonfarm sector; (5) unemployment; (6) per capita disposable income; and (7) prices received by farmers. Proposed changes in the parameters of the model include variation of production elasticities for fertilizer and lime, and for labor. To reflect different levels of neutral technological change, the constant term in the production functions will undergo changes. These variations will be made singly and in combination in order to answer questions concerning farm income and resource use under alternative conditions.

Changes in data and parameters in the following section are organized under four main categories. In the first of these the implications of free market conditions on agricultural prices and incomes are investigated. Secondly, the effect of government programs on agricultural resource use is examined. The third category looks at the effect of nonfarm variables on the farm economy in general. Finally, the effect of changes in production function parameters are related to agricultural prices, incomes, and resource use.

In order to simplify the presentation of the various simulation runs each will be numbered and frequent references to tables of averages will be made. The numbering of simulation runs is as follows:

I. The original simulation model with no changes in data or parameters.

II. Government diversions (GD), government payments to farmers (GP), and acreage diversions (ADIV) are set at zero.

III. Cropland acreage (AC) is fixed at 300 million acres.

IV. Prices received (PR) are fixed at the levels of prices paid in the preceding year.

V. Unemployment (U) is zero and the disposable income series (YD) is increased by 10 percent throughout.

VI. Same as V, except prices paid for inputs are also increased by 10 percent.

VII. Prices paid for inputs are increased by 10 percent throughout.

VIII. Unemployment (U) is zero and disposable income (YD) is increased by two percent per year.

IX. Unemployemnt (U) and disposable income (YD) are fixed at their 1930-39 averages.

X. Fertilizer and lime production elasticity is doubled.

XI. Labor production elasticity is halved.

XII. Changes in X and XI combined.

XIII. Intercept term in the production function is increased by one percent per year.

XIV. Same as XIII except the increase is three percent per year.

XV. Intercept term in the production function decreased by one percent per year.

Implications of Free Market Conditions for Agricultural Prices and Incomes

Because government programs and policies in the past have not resulted in complete satisfaction to farmers and others in the nonfarm economy, there is frequent consideration of a possible return to "free-market" conditions for agriculture. Government purchase and storage of basic crops receive the major portion of the attention of free market advocates. In the following simulation (Simulation II) the effects of no diversions of excess production, no acreage controls, and a cessation of government payments to farmers are considered.

Effects on Prices Received and Gross Farm Income

Estimates of the quantities of agricultural production diverted from commercial markets by the Commodity Credit Corporation have been made by Tyner and Tweeten for 1955-62[1] and by Hathaway and Stollsteimer for 1948-56.[2] Data were calculated to extend this series back to 1930, as explained in Appendix A, Table II.

This activity of the CCC was authorized as an attempt to support farm income. Prices received in the commercial market would be higher because of the reduced volume of sales and the inelastic demand, and farmers would also receive a specified price for products assigned to CCC. If market prices became more favorable during the loan period, loans could be redeemed by farmers and the products sold in the commercial market.

The adverse income effects of placing these quantities on the market can be estimated for the short run (the first-order effects) by using the elasticity of demand formula. Such an estimate, however, does

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[1] Fred H. Tyner and Luther G. Tweeten, "Excess Capacity in U. S. Agriculture," Agricultural Economics Research, January, 1964, pp. 23-31.

[2] Dale E. Hathaway and John F. Stollsteimer, The Impact of Price Support Programs Upon the Available Supplies of Farm Products, 1948-56, Technical Bulletin No. 277, Michigan State University, East Lansing, May, 1960.

not provide an indication of changes in resource use, nor does it picture the cumulative effects, over a period of years, of changes in the CCC diversion programs. Use of a structural economic model allows the tracing of these cumulative effects through the simulation process. By using such a procedure, the long-run or second- and higher-order effects of changes in government programs may be observed. Simulation of the model with the variable GD (CCC net removals) set equal to zero is an attempt to portray what would likely have happened had the CCC program not been initiated.

Average levels of key variables for 1930-40, 1941-50, and 1951-60 are given in Tables VII and VIII. For the 1930-60 period, estimates of prices received in the absence of government diversions of production, government payments, and acreage controls averaged 7.0 percent lower than the estimates of Simulation I. Estimates of PR for 1951-60 averaged 81.4 and 68.0, respectively, for Simulations I and II. This is an index of 17.5 percent less than with government programs during the period when excess production was a greater problem.

The effect of a lower level of prices received when government programs are absent is apparent in the level of gross farm income. For the 1951-60 period, average GFI estimates are 13 percent lower than was estimated in Simulation I (27,660.0 million 1947-49 dollars compared with 31,717.7 million 1947-49 dollars).

Effects on Net Income

Average net farm income for 1951-60 can be calculated by subtracting the value of all inputs from gross farm income. Total inputs for

TABLE VII

AVERAGE LEVELS OF INPUT USE FOR SIMULATIONS I, II, III, AND IV; 1930-40, 1941-50, AND 1951-60

Simulation	Period	Input									
		FL	FSL	XM	RE	FOE	XMIS	XINT	RET	Total	TFLF
		million 1947-49 dollars									1,000
I	1930-40	284.5	1,024.0	1,061.0	3,337.4	712.7	1,143.6	1,101.8	807.7	9,472.7	9,853.9
	1941-50	697.2	1,739.3	1,530.1	3,514.4	1,593.7	1,358.6	1,287.0	642.8	12,363.1	8,528.3
	1951-60	1,286.5	2,597.7	2,648.0	3,737.1	2,536.1	2,015.5	1,425.3	851.8	17,098.0	6,435.1
II	1930-40	285.0	1,024.7	1,057.7	3,335.9	716.6	1,142.6	1,102.1	804.0	9,468.5	9,859.7
	1941-50	699.3	1,742.4	1,522.8	3,505.4	1,608.1	1,356.3	1,287.8	625.8	12,347.9	8,541.0
	1951-60	1,296.7	2,609.7	2,610.1	3,699.2	2,513.7	2,004.8	1,428.1	776.3	16,937.5	6,501.3
III	1930-40	288.3	1,057.5	1,042.1	3,323.5	1,472.9	1,138.3	1,113.3	774.8	10,210.7	9,886.9
	1941-50	704.2	1,803.0	1,513.9	3,480.6	2,410.9	1,353.5	1,297.4	579.6	13,143.1	8,556.6
	1951-60	1,294.3	2,657.3	2,629.2	3,692.5	3,183.5	2,010.0	1,406.9	763.0	17,636.7	6,467.9
IV	1930-40	273.4	1,005.3	1,111.9	3,380.6	612.4	1,156.9	1,096.2	911.9	9,548.6	9,764.8
	1941-50	691.9	1,728.9	1,528.2	3,554.6	1,553.3	1,358.1	1,287.6	719.9	12,423.5	8,531.6
	1951-60	1,273.7	2,582.3	2,694.7	3,805.3	2,516.5	2,029.4	1,421.9	986.6	17,310.3	6,353.4

TABLE VIII

AVERAGE LEVELS OF OUTPUT, PRICES RECEIVED, AND GROSS FARM INCOME FOR ALL SIMULATIONS; 1930-40, 1941-50, and 1951-60

Simulation	OUT			PR			GFI		
	1930-40	1941-50	1951-60	1930-40	1941-50	1951-60	1930-40	1941-50	1951-60
	----million 1947-49 dollars--			------1947-49 = 100------			--million 1947-49 dollars--		
I	20,859.4	26,645.5	32,390.0	69.6	93.1	81.4	19,079.3	30,489.2	31,717.7
II	21,084.7	26,406.2	32,276.0	68.2	91.0	68.0	18,657.0	29,876.5	27,666.0
III	22,104.9	27,196.6	33,036.8	58.2	84.2	74.1	17,019.0	28,643.8	29,679.2
IV	20,980.6	26,425.3	32,534.4	89.4	93.4	95.2	23,981.0	30,832.5	37,105.7
V	20,601.9	26,066.1	32,028.4	79.4	103.6	92.8	20,964.2	33,232.7	35,526.1
VI	18,298.8	21,374.7	28,839.4	105.2	156.2	128.6	23,711.4	39,599.3	42,618.7
VII	18,814.4	22,407.6	30,221.4	95.1	137.8	105.7	22,297.8	37,002.4	37,330.0
VIII	20,596.6	25,989.0	32,131.6	81.3	124.0	136.0	21,406.5	39,495.9	51,594.0
IX	23,269.1	27,224.0	32,754.3	68.7	49.4	30.4	18,949.0	17,341.9	13,152.8
X	21,037.7	26,386.6	32,392.1	70.2	93.2	81.3	19,173.0	30,499.9	31,698.7
XI	21,179.0	26,408.0	32,297.6	68.6	93.0	82.4	18,905.7	30,427.4	32,123.7
XII	20,698.0	26,317.1	32,275.8	74.0	94.0	82.6	19,784.4	30,555.5	32,170.7
XIII	21,313.9	26,696.3	32,701.9	67.1	89.8	77.9	18,642.4	29,811.7	30,748.2
XIV	21,777.4	27,281.1	33,312.1	61.9	83.2	71.0	17,718.1	28,395.7	28,770.6
XV	20,849.8	26,103.2	32,074.1	72.3	96.4	84.9	19,503.1	31,143.8	32,671.3

the period (excluding labor) averaged $16,937.5 million. Man hours worked averaged 12,688.7 million per year. Total labor cost is calculated by charging 85 percent of the hourly nonfarm wage as the cost of both hired and family labor.[3] The adjusted hourly wage equals $1.34, giving a labor cost of $17,002.9 million. Net income is calculated to be negative (-$6.3 billion).

Net returns to family labor, which may be more meaningful, can be calculated by charging only for hired labor. Approximately 27.1 percent of total man-hours worked from 1951-60 was attributed to hired labor. Average hourly earnings for hired labor were $.698. Assuming the same distribution between family and hired labor in Simulation II, average hours worked by hired labor are 3,438.6 million. The hired labor cost is thus $2400.1 million ($.698 x 3438.6). Net returns to family labor (GFI-costs) are $8,328.4 million.

Net returns to family labor calculated in the same manner for Simulation I are $12,252.7 million. Average net returns to family labor are therefore lower by $3,924.3 million or 32 percent annually in the absence of the government programs.

The ratio of family labor force to total labor force for 1951-60, as estimated by the USDA, is .752. By using this as a percentage to estimate the family labor force involved in Simulations I and II, average annual net returns to labor per family worker[4] are lower by $828 or

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[3] Omitting 15 percent of the nonfarm wage compensates for differences involving family size and consumption of farm-produced foods. Cf. Hathaway, p. 37.

[4] Estimated family workers are 4,839,200 for Simulation I; 4,888,978 for Simulation II. The effect of government programs on resource use, especially labor, will be discussed in the following section.

33 percent in the absence of government removals of excess production, payments to farmers, and acreage controls. Because of different assumptions, these results cannot be compared directly with those from other analyses of reduced government participation in agriculture. They are not inconsistent with other findings, however, and indicate a considerable drop in farm income even when the secondary effects on labor and other resources are considered.

The Effect of Government Programs on Agricultural Resource Use

The simulation reflecting free market conditions for agriculture provides the initial basis for analysis of the effects of government programs on agricultural resources. Estimates from Simulation II relating to changes in use of resources are discussed below. In addition, the effects of a change in acreage control programs (Simulation III) and the effects of an arbitrarily fixed level of prices received by farmers (Simulation IV) are examined.

Government Diversions, Payments, and Acreage Controls

The estimated impact of government diversions of excess production, etc., on use of agricultural resources is an annual reduction in total input use (excluding labor) of $160.5 million for the 1951-60 period. The machinery stock input decreases $38 million; real estate decreases by $38 million; fuel and operating expense decreases by $23 million; and miscellaneous inputs decrease by $11 million. Real estate tax expense decreases most, by over $75 million, as a result of devaluation of agricultural real estate in the absence of these government programs.

Inputs showing an increased use are fertilizer and lime ($9.2 million), and feed, seed, and livestock ($12.0 million).

Effect on farm labor force. One of the more interesting points which may be examined is the effect of government programs on the agricultural labor force. An hypothesis frequently advanced is that government programs have had an undesirable effect on the farm labor force, retarding the outflow of a resource that is conceded to be in excess. Results obtained in this simulation are contradictory to that hypothesis. The estimated farm labor force is, in fact, higher by 66,200 workers or 1.0 percent in the absence of the government programs than was estimated in Simulation I. This indicates that the programs have aided or encouraged the movement of farm labor to nonfarm employment, although the percentage change above is not great.

This effect apparently occurs as a result of higher farm income when government programs are in effect, allowing for the purchase of additional or more efficient machinery and equipment, thereby decreasing the need for labor. Also, the programs have increased the value of farm real estate. This represents a barrier to entry for prospective new farmers. Those farmers who wish to sell their farms thus obtain a larger "stake" to finance the transition to nonfarm employment. But the sales tend to be for farm enlargement rather than for new starts in farming.

The simulation model is based on past rates of labor response and hence considers adjustments to be "orderly." If there were a higher rate of bankruptcy, farm labor would move out at a much faster rate; however, society would likely not tolerate this condition.

Results of Simulation II cast considerable doubt on the ability of sharply depressed farm economic conditions to solve the vexing problem of excess labor in farming. In fact, the simulation points to a possible result of farm programs hardly intended by most program supporters--a reduction in farm worker numbers due to security and capital provided to purchase labor-substituting capital inputs.

Acreage Control Programs

For various reasons--including chiefly the unwillingness of legislators to interfere in farm operating decisions and the difficulty of enforcement--acreage control programs were a late addition to the set of production control procedures. Additionally, cross-compliance measures to prevent the planting of alternative crops were not among the features of the first acreage control type programs.

As indicated in Chapter IV, effective acreage control programs began in 1956. This was some 26 years after the CCC program began, and long after it had become apparent that production control measures were needed. Acres of cropland used for crops averaged 376 million acres from 1930-55, and only 359 million acres from 1956-60. The simulation below examines the effect on farm income under the assumption that acreage diversions in each year were such that acres of cropland planted equaled 300 million from 1930-60.

With cropland acres limited to 300 million, output could be expected to decline. This, of course, was the philosophy advanced when acreage control programs were introduced in the 1950's. The results of this simulation are similar to the effect the programs of the 1950's had on output--an increase.

Compared to Simulation I, output increased by an average of \$0.9 billion for the 1930-50 period and by \$0.6 billion annually for 1951-60. Inputs showing an increase for 1951-60 with acres of cropland restricted are: fertilizer and lime (\$8 million); feed, seed, and livestock (\$59.6 million); and fuel and operating expense (\$647 million). These results may be explained on the basis that acreage restrictions only placed pressure on farmers to speed the profitable changes that were overdue--toward productive fertilizer and other operating inputs. These profitable and productive inputs more than compensated for the decrease in cropland acreage.

The large increase in fuel and operating expense is consistent with the use of smaller, less efficient machines and more intensive tillage caused by acreage reductions. Machinery stock decreases by only \$19 million but this small reduction is also consistent with a lower level of technology. Other inputs decreasing in the 1951-60 period are real estate (\$44.6 million), miscellaneous (\$5 million), interest on crop and livestock inventory (\$18.4 million), and real estate taxes (\$88.8 million). Net changes in input use (excluding labor) are an increase of \$637 million. The work force increased by 32.8 thousand workers over the estimate of the original model (Simulation I).

Prices Received Fixed

Farmers as a group react to higher prices in year t by increasing production in year t + 1. The price variable and its covariable, gross farm income, are introduced into several of the equations in the pre-input or "decision" section of the simulation model. Preceding simulations have allowed prices received (PR) and gross farm income (GFI) to be estimated endogenously in each iteration of the simulation. In Simulation IV below, this condition is omitted, and the level of PR for each year during the entire period is taken as given. The PR series is adjusted to the index of prices paid so that the ratio of the two (which is the parity ratio) is 100. The assumption underlying this simulation is that the general level of prices received for year t is supported at the level that would have insured parity prices for year t - 1.

The average level of prices received for Simulation IV is 89.4 for 1930-40, 93.4 for 1941-50, and 95.2 for 1951-60, compared to estimates of 69.6, 93.1, and 81.4 for the same periods in Simulation I. Average output for 1930-40 is higher by $121 million with the higher price level. For 1941-50, average output is lower because the fixed level of PR is below the actual level (Simulation I) for the first six years of the period. Effects of a higher PR are seen only at the end of the 1941-50 period and in 1951-60. Estimates of output for the 1951-60 period are increased by $144 million. With output slightly higher and with the supported price level, gross farm income increases to $37.1 billion (1951-60 average). This is 17 percent higher than the estimates obtained when price was determined each year in the original model.

The simulation model contains an implicit supply function since input levels are determined first and are converted into output estimates by the production function. For the 31 year period, prices received average 14 percent higher under Simulation IV, while output averages less than one percent higher, which could imply a low aggregate supply elasticity. Such a conclusion is not appropriate, however. The adjustment in prices received resulted in considerably higher prices in the early part of the period. During the middle and later years prices received were approximately equal to or lower than those in Simulation I. Because PR was fixed at the beginning of each year there was no opportunity for cumulative effects of high prices received to influence output.

Total inputs (excluding labor) increased slightly--by 1.2 percent for 1951-60. Changes in the use of individual inputs for 1951-60 were: increased for machinery stock expense of $46.7 million; for real estate of $68 million; for miscellaneous of $14 million; and for real estate taxes of $135 million--and decreases for fertilizer and lime of $5 million; for feed, seed, and livestock of $15 million; for fuel and operating expense of $20 million; and for interest on crop and livestock inventory of $3 million. The total farm labor force estimate decreases by about 82,000 workers.

Net returns to family labor for Simulations III and IV. Effects of cropland acreage being fixed at 300 million acres and prices received supported at parity levels on the farm labor force were outlined above. What happens to net income and income per family worker are even more important. With cropland acreage fixed at 300 million acres, net returns to family labor average $9.7 billion for 1951-60. With an average estimated family labor force of 4,863,900, net returns per family worker are $1,985.90. This is 22 percent less than the income figure for Simulation I.

With a high level of price supports (Simulation IV) net returns to family labor average $17.5 billion--almost double the estimate in the preceding situation, and over 40 percent above Simulation I. Income per family worker is increased $1,124.40 over Simulation I to $3,656.40.

Effect of Nonfarm Variables on the Farm Economy

As mentioned previously, the agricultural sector has become increasingly dependent on the nonfarm sector. This is apparent in the proportion of farm inputs that are being purchased from the nonfarm sector rather than farm-produced. Additionally, the dwindling size of the farm sector in the total economic picture magnifies the effect of occurrences in the nonfarm sector on farm variables. An attempt is made in this section to determine the magnitude of effects on the farm economy by introducing selected changes in employment, disposable income, and input prices into the model.

The level of employment in the nonfarm sector influences farm income and resource use. Indirectly, full employment implies prosperity and a higher level of disposable income, which tends to increase the demand for agricultural products. The direct effect of full employment is to reduce the available supply of hired labor for agriculture, and to attract farm family labor to jobs outside agriculture. This tends to encourage the combination of farms into units of more efficient size and to speed the adoption of machine technology.

Increases in disposable income tend to raise the level of prices received by farmers, as indicated in the demand equation of the simulation model. The tendency of higher incomes to inflate the prices of inputs purchased from the nonfarm sector was mentioned earlier. Since there is no structural mechanism in the model to incorporate this effect, the model is first simulated below with a higher level of disposable income but unchanged input prices and with unemployment set equal to zero to reflect national prosperity without inflation. In a second simulation it is assumed that full employment exists and that both disposable income and input prices are higher to reflect prosperity with inflation. The third simulation maintains unemployment and disposable income at actual levels, but input prices are 10 percent higher. The latter simulation reflects inflation without national prosperity of the type experienced when wage demands in industry are passed on as higher input prices to farmers. The disposable income series is increased 2.0 percent per year with unemployment equal to zero in the fourth simulation. Finally, income and unemployment are fixed at their 1930-39 average for the fifth simulation to reflect depressed economic conditions in the national economy.

No Unemployment, Higher Disposable Income

The effect of no unemployment, with disposable income increased by 10 percent over the 1930-60 period, and with other variables unchanged, is seen in the results of Simulation V.

The key variables to be considered are the size of the farm labor force, farm output, prices received, and gross farm income. Output, price, and income estimates are given in Table VIII. Estimates of resource use are shown in Table IX. The more prosperous nonfarm sector exemplified by this simulation provides an outlet for unemployed or underemployed farm labor. For the 1930-50 period the farm labor force

TABLE IX

AVERAGE LEVELS OF INPUT USE FOR SIMULATIONS V, VI, VII, VIII, AND IX; 1930-40, 1941-50, AND 1951-60

Simulation	Period	Input									
		FL	FSL	XM	RE	FOE	XMIS	XINT	RET	Total	TFLF
		million 1947-49 dollars									1,000
V	1930-40	281.5	1,008.4	1,077.4	3,348.7	678.3	1,148.1	1,095.8	834.1	9,472.3	9,359.6
	1941-50	689.0	1,702.4	1,553.0	3,551.4	1,522.5	1,365.8	1,280.9	711.9	12,376.9	8,285.0
	1951-60	1,274.6	2,558.6	2,681.9	3,798.9	2,516.2	2,025.5	1,418.2	973.6	17,247.4	6,149.8
VI	1930-40	109.7	950.7	1,104.0	3,365.7	246.0	985.9	1,073.9	895.9	8,711.1	9,254.1
	1941-50	174.2	1,475.7	1,609.2	3,616.4	229.4	1,218.5	1,226.1	833.8	10,383.3	8,103.7
	1951-60	749.2	2,263.5	2,751.4	3,930.9	1,349.0	1,897.3	1,375.3	1,233.8	15,550.5	5,929.2
VII	1930-40	110.4	965.6	1,089.1	3,356.6	258.4	982.4	1,078.8	853.7	8,695.0	9,792.6
	1941-50	181.1	1,528.2	1,585.2	3,587.5	370.8	1,212.0	1,238.8	779.6	10,483.2	8,369.2
	1951-60	769.6	2,360.6	2,702.6	3,863.7	1,718.6	1,883.2	1,395.2	1,101.0	15,794.4	6,263.2
VIII	1930-40	281.5	1,008.3	1,079.8	3,348.6	676.1	1,148.9	1,095.6	834.0	9,472.7	9,355.4
	1941-50	679.4	1,687.4	1,601.2	3,587.1	1,452.0	1,380.5	1,275.4	779.1	12,442.1	8,200.8
	1951-60	1,239.1	2,507.1	2,814.7	3,949.9	2,474.6	2,065.7	1,405.5	1,272.7	17,729.4	5,917.5
IX	1930-40	287.1	1,025.9	1,066.2	3,340.5	709.3	1,143.9	1,102.4	813.3	9,488.6	9,913.2
	1941-50	714.0	1,787.8	1,413.2	3,440.7	1,739.5	1,326.2	1,305.4	505.6	12,232.4	9,284.4
	1951-60	1,341.4	2,716.4	2,476.2	3,491.8	2,622.4	1,966.1	1,446.8	367.5	16,428.6	7,410.3

is smaller by 375,000 workers than the estimate of the original model. For 1951-60 the average level is 285,000 less.

Farm output averages $411 million and $363 million less for the 1930-50 and 1951-60 periods, respectively. This lower output, in conjunction with increased demand due to higher disposable income, results in higher prices received by farmers. Average prices received are 79.4, 103.6, and 92.8 for 1930-40, 1941-50, and 1951-60, compared with estimates of 69.6, 93.1, and 81.4 in Simulation I. Gross farm income in the three periods increases by an average of $1.9 billion, $2.7 billion, and $3.8 billion, respectively. It is clear that fiscal and monetary policies to foster a growing national economy constitute one of the most effective means to raise income and reduce excess labor in agriculture.

No Unemployment, Higher Disposable Income, and Higher Input Prices

The adoption of improved farming technology has resulted in a substantial increase in the quantities of inputs purchased from the nonfarm sector. U. S. Department of Agriculture estimates of these purchases show an increase in the index of expenditures from 58 in 1930-34 to 103 in 1960 (1957-59 = 100).[5] This increasing dependence is a unilateral phenomenon, since the demand from agriculture is only a minor fraction of the total demand for such items as steel products, chemicals, and petroleum products. Also, the income elasticity of demand for such

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[5] U. S. Department of Agriculture, Changes in Farm Production and Efficiency, Statistical Bulletin 233 (Washington, 1965), p. 36.

products appears to be relatively high in the nonfarm economy,[6] the implication being that prices of these inputs may increase independently of demands from the farming sector.

The supply of production inputs purchased from the nonfarm sector (with the exception of hired labor) is assumed, for the purposes of this study, to be approximately elastic. That is, at the prevailing price, the quantity of inputs available does not impose a limit on farm production. Given a less than completely elastic supply curve for steel, chemical, and petroleum products, gains in nonfarm income tend to increase the prices of these products.[7] Higher labor costs not compensated by productivity are passed on to farmers. At the same time, there is not an immediate offsetting higher price for farm products.

Simulation VI examines the effects of farm income and resource use of increases in the prices of selected inputs purchased from the nonfarm sector. Input prices employed in the model are the price of fertilizer (PF), the price of nonfarm labor (PNF), the price of motor supplies (PMS), and the price of general farm supplies (PFS). Each series is increased by ten percent throughout the 1930-60 period in the following simulation.

With full employment and a 10 percent increase in disposable income and input prices, output is decreased considerably. Average output is lower in 1930-40, 1941-50, and 1951-60 by \$2.6 billion, \$5.3 billion, and \$3.6 billion, respectively. These are the lowest output estimates

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[6] Hathaway, p. 143.

[7] Ibid.

obtained for any of the simulations. Because of lower output and increased demand due to higher disposable income, prices received are exceeded only by the 1951-60 estimate in Simulation VIII. The average index is 105.2, 156.2, and 128.6 for 1930-40, 1941-50, and 1951-60, compared with estimates of 69.6, 93.1, and 81.4 in Simulation I for the same periods. Gross farm income estimates of \$23.7 billion, \$39.6 billion, and \$42.6 billion for the three periods are the highest estimates obtained, again excepting the 1951-60 estimate for Simulation VIII.

Major differences in input use between this simulation and the preceding one (Simulation V) are not limited to the inputs affected by higher prices, though these inputs show the most striking changes. Fertilizer and lime inputs for 1951-60 are \$525 million (41 percent) lower. Because of higher prices paid for motor supplies, the category of fuel and operating expense shows an average decrease of \$1,167 million for the 1951-60 period. Miscellaneous inputs, influenced by higher prices of farm supplies, decreased an average of \$128 million. Other inputs undergoing changes from the preceding simulation over the 1951-60 period were: feed, seed, and livestock (a decrease of \$295 million); machinery (an increase of \$70 million); real estate (an increase of \$132 million); inventory interest (a decrease of \$43 million); and real estate taxes (an increase of \$260 million). Total inputs, excluding labor, are decreased by \$1,697 million. The farm labor force decreased by 221,000 workers.

Comparison of gross income estimates from this simulation with the estimates from Simulation I shows a 34 percent increase in average income for the 1951-60 period. The farm labor force declines by 8.0

percent, and total input use, excluding labor, declines by 9.0 percent. The combined decrease in inputs other than labor directly affected by price increases (FL, FOE, XMIS) amounts to 32 percent of the estimated levels in Simulation I.

Higher Input Prices

In Simulation VII prices of inputs are inflated by 10 percent throughout the 1930-60 period, but unemployment and disposable income are at their actual levels in each year, representing inflation without prosperity. This probably gives a more realistic picture of the problems of displaced farm workers finding nonfarm employment, and corresponds to a lower demand for farm products.

The total farm labor force is consistently higher in this simulation than in Simulation VI. In 1951-60 the farm labor force is larger by 334,000 workers (or 5.3 percent) than when unemployment is zero and disposable income is higher.

Gross farm income is again higher than in Simulation I. This is due to lower output and its associated higher level of prices received. Output is lower by 10 percent in 1930-40, 16 percent in 1941-50, and 7.0 percent in 1951-60. Prices received are higher by 37 percent, 48 percent, and 30 percent for the same three periods. The implications of Simulations VI and VII are that farmers should favor moderate inflation--in the first case (Simulation VI) demand for farm products, and in both simulations higher input prices tend to decrease output, raising the level of prices received for farm products. An hypothesis widely held is that farmers are severely disadvantaged in earnings by inflation without national prosperity, and that higher prices paid by farmers are not compensated by higher prices received. But the above results indicate that farmers make input adjustments which reduce output and hence, in time, increase farm prices and incomes to offset higher input prices.

Disposable Income Increased Two Percent per Year and Unemployment Zero

Simulation VIII is run as an alternative to Simulation V. Instead of increasing the entire YD series by 10 percent, each YD observation is multiplied by $(1.02)^i$, $i=1, 2, \ldots, 31$. This gives the effect of a 2.0 percent rate of inflation in YD, assuming that there is no inflation in the actual data series.[8]

Input comparisons between Simulations VIII and V show the same average use (excluding labor) in 1930-40, a less than 1.0 percent increase in 1941-50 and a 2.8 percent increase in 1951-60. Because the farm labor force decreases by 4.0 percent for 1951-60, output is only slightly above the Simulation V estimate. Higher levels of disposable income cause a considerable increase in prices received, so that gross farm income is higher by 2.0 percent, 19 percent, and 45 percent for 1930-40, 1941-50, and 1951-60, respectively, as the income effect accumulates.

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[8] The YD series has been deflated by the implicit price deflator of the gross national product as the basis for this assumption (See Appendix A, Table II).

Unemployment and Disposable Income at Depression Levels

Data for unemployment (U) and disposable income (YD), which enter the model exogenously, are fixed at their respective averages for 1930-39 in Simulation IX to determine the effect of a continued depression in the nonfarm sector on the farm economy. Estimates under these assumptions compared to the original model show the following results.

Output increases slightly in all three periods (by 12 percent in 1930-40, 2.0 percent in 1941-50, and 1.0 percent in 1951-60). The average price level decreases to 68.7, 49.4, and 30.4 for the three periods, as compared to 69.6, 93.1, and 81.4 in the original model (Simulation I). Consequently, gross income decreases to $18.9 billion, $17.3 billion, and $13.2 billion for 1930-40, 1941-50, and 1951-60, respectively.

Considering only the 1951-60 period, total input use (excluding labor) is decreased by $669 million. The most significant changes in the use of individual inputs are: a decrease of $172 million in machinery stock expense; a decrease of $245 million in real estate; a decrease of $49 million in miscellaneous inputs; and a decrease of $484 million in real estate taxes--increases in fertilizer and lime ($55 million); feed, seed, and livestock ($120 million); and fuel and operating expense ($86 million). The total farm labor force increases by 975,000 workers.

This combination of lower gross income and a million more workers in the farm labor force would have serious consequences for labor earnings in agriculture. The attractiveness of national goals of full employment and growth again are strongly highlighted by these results. Fiscal and monetary policies directed toward achieving these goals in the past have been richly rewarding.

Net Returns to Family Labor

Net returns to family labor for Simulations V, VI, VII, and VIII during 1951-60 with changes in nonfarm variables are shown in Table X. With prosperity in the nonfarm sector and unchanged input prices (Simulation V) total net returns and returns per family worker are 31 percent and 37 percent higher than under Simulation I. However, when input prices are increased net returns rise even more--more than double the estimates for Simulation I.

TABLE X

NET RETURNS TO FAMILY LABOR AND PER FAMILY WORKER FOR SIMULATIONS V, VI, VII, AND VIII; 1951-60

Item	Unit	Simulation			
		V	VI	VII	VIII
Total net returns	Mil. 1947-49 Dol.	16,054.80	24,955.10	19,254.80	31,757.20
Per worker returns	Dol.	3,471.60	5,596.80	4,088.20	7,136.40

The output-decreasing effect of higher input prices alone is greater than the effect of prosperity in the nonfarm sector without higher input prices. Comparison of Simulations VII and V shows an increase of 20 percent in total net returns and an increase of 18 percent in net returns per family worker.

Increasing disposable income by 2.0 percent per year (Simulation VIII) gives the highest income estimates obtained. Total net returns are 2.5 times as large as for Simulation I, and returns per worker are 2.8 times as great.

Effect of Changes in Production Coefficients

The procedure used in developing production elasticity estimates for nine categories of farming inputs was given in Chapter III. It was hoped that the estimates derived would be good approximations of the true parameters. In the cases of fertilizer materials and labor the estimates did not agree with a priori expectations. Fertilizer may, in fact, be more productive than its elasticity estimate indicates. Conversely, labor productivity may have been overestimated. It is desirable to know whether errors in estimating these parameters might significantly affect the levels of the simulation estimates of key variables in the model. Assuming that the original parameter estimates are accurate, it is also desirable to estimate changes in input combinations resulting when fertilizer inputs are more productive and when labor is less productive.

To use the production function with a different set of production elasticities, it is necessary to recalculate the a-values. The procedure used is the same as that used in calculating the original a-values, and is explained in Chapter III.

Three simulation runs (Simulations X, XI, and XII) are presented in this section based on different production elasticities for these two input categories. In the first simulation the fertilizer and lime production elasticity is doubled. In the second, the coefficient of labor is halved, and in the third these changes are included in the same simulation. Simulation estimates of output, price, and incomes are given in Table VIII. Table XI shows estimates of input use.

The rapid adoption of technology has been mentioned as a cause of income-depressing increases in output. These technological innovations

TABLE XI

AVERAGE LEVELS OF INPUTS FOR SIMULATIONS X, XI, XII, XIII, XIV, AND XV; 1930-40, 1941-50, AND 1951-60

Simulation	Period	Input									
		FL	FSL	XM	RE	FOE	XMIS	XINT	RET	Total	TFLF
		million 1947-49 dollars									1,000
X	1930-40	284.3	1,021.7	1,062.1	3,338.5	709.9	1,143.8	1,101.1	809.9	9,471.3	10,837.2
	1941-50	696.7	1,735.5	1,530.4	3,516.5	1,589.7	1,358.8	1,286.6	646.6	12,360.8	8,527.7
	1951-60	1,286.4	2,597.1	2,648.2	3,738.3	2,538.0	2,015.5	1,425.3	854.2	17,103.2	6,434.7
XI	1930-40	284.9	1,027.7	1,059.5	3,336.0	717.0	1,143.2	1,102.8	804.0	9,475.1	9,856.5
	1941-50	696.9	1,738.1	1,531.0	3,514.5	1,590.0	1,358.9	1,286.3	642.9	12,358.6	8,526.8
	1951-60	1,287.2	2,603.4	2,649.1	3,734,2	2,548.3	2,015.6	1,425.5	846.2	17,109.4	6,433.1
XII	1930-40	283.3	1,011.4	1,067.7	3,342.2	694.7	1,145.4	1,097.3	818.6	9,460.6	9,842.1
	1941-50	694.7	1,715.2	1,532.9	3,526.3	1,567.2	1,359.7	1,284.4	664.9	12,345.3	8,523.4
	1951-60	1,286.4	2,596.0	2,648.5	3,741.9	2,549.1	2,015.7	1,425.3	861.4	17,124.3	6,434.3
XIII	1930-40	285.4	1,031.5	1,057.0	3,334.5	723.0	1,142.4	1,104.4	800.8	9,479.0	9,860.9
	1941-50	699.0	1,756.6	1,524.5	3,505.9	1,613.6	1,356.9	1,290.6	627.0	12,373.9	8,538.1
	1951-60	1,289.6	2,620.9	2,639.3	3,721.7	2,543.8	2,013.0	1,429.4	821.3	17,079.0	6,450.3
XIV	1930-40	287.0	1,046.6	1,048.6	3,328.3	744.4	1,140.1	1,109.5	786.2	9,490.7	9,875.6
	1941-50	702.9	1,791.1	1,512.7	3,488.1	1,650.7	1,353.2	1,297.8	593.7	12,390.2	8,558.7
	1951-60	1,295.9	2,667.3	2,621.5	3,689.5	2,558.9	2,007.7	1,437.6	758.0	17,036.3	6,481.5
XV	1930-40	283.8	1,016.6	1,064.8	3,340.4	702.3	1,144.6	1,099.2	814.5	9,466.2	9,847.2
	1941-50	695.4	1,722.0	1,535.6	3,522.5	1,573.5	1,360.3	1,283.4	658.1	12,350.7	8,518.7
	1951-60	1,283.6	2,574.4	2,656.5	3,752.1	2,528.2	2,018.0	1,421.1	881.3	17,115.2	6,420.2

have mostly involved only a few of the input categories. Analysis of different rates of adoption of technology for separate inputs is difficult, however. For this reason, different levels of neutral technological change are assumed, and the intercept terms of the production functions are varied in Simulations XIII, XIV, and XV. The purpose of these simulations is to examine the effect of two higher rates and one lower rate of adoption of new technology.

Fertilizer and lime production elasticity doubled. Total input use, excluding labor, is down only \$1.9 million for 1930-50, and is up \$5 million for 1951-60. For the later period the real estate input is increased by \$1.2 million; fuel and oeprating expense is increased by \$1.9 million; and real estate taxes are up by \$2.4 million. Average 1951-60 output is \$2.1 million higher but a slightly lower index of prices received (81.3 compared to 81.4) causes a drop in gross income of \$19 million. However, this is a decrease of less than 0.1 percent in income. The farm labor force is reduced by less than 1,000 workers.

Labor production elasticity halved. Total input use is lower than the level estimated in the original model by \$1 million in 1930-50 and higher by \$11 million in 1951-60. The average farm labor force is lower in 1951-60 by 2,000 workers. Changes in individual inputs for the later period are: an increase of \$6 million in the feed, seed, and livestock input; an increase of \$1 million in the machinery input; a decrease in the real estate input of \$3 million; an increase in fuel and operating expense of \$12 million; and a decrease in real estate taxes of about \$6 million.

Output for 1951-60 is $92 million lower, prices received are one index point higher, and gross income is increased by $400 million dollars, an increase of one percent.

Simultaneous changes in production elasticities. In this simulation the preceding changes in production elasticities are made in the same run; i.e., the fertilizer and lime production elasticity is doubled and the labor production elasticity is halved. Again, estimates of input use are quite close to estimates from the original model. Inputs showing increases for 1951-60 are: real estate ($4.8 million); fuel and operating expense ($13 million); and real estate taxes ($9.6 million). Percentage increases were small with input levels being 0.1, 0.5, and 1.1 percent higher, respectively, than the estimates of the original model.

For the 1951-60 period, output decreases by $114 million (0.3 percent), prices received increases by 1.2 index numbers (1.5 percent), and gross farm income increases by $453 million (1.4 percent).

Summary of production elasticity changes. The three simulations with changes in production function parameters were run to examine potential effects of possible errors on estimates of key variables. Results are not intended to indicate whether errors in parameter estimates in fact were present--but the sensitivity analysis does indicate that estimates of key variables are not appreciably altered by changes in the production coefficients.

One percent neutral increase in technology. Simulation XIII was run to examine the effect of a 1.0 percent per year increase in technology. The increase is assumed to be neutral. Hence only the intercept term of the production function rather than individual production elasticities is varied.

A comparison between the results of Simulations XIII and I shows only slight changes. Total input usage is higher in 1930-40 and 1941-50, and lower in 1951-60. Farm labor force numbers are higher in each of the three periods by 7,000, 10,000, and 15,000 workers. Technological improvements in farm inputs are normally expected to result in a lessened need for labor. Organization of equations and variables in the simulation model give higher labor force estimates because higher output means lower prices received and lower gross farm income. Lower income means a decrease in machinery purchases and lowers the average stock of machinery. The labor force estimate increases because of the negative coefficient on the machinery stock variable.

Output is increased by 2.0 percent, less than 1.0 percent, and 1.0 percent in the respective periods. Prices received are moderately lower due to the increased output and gross farm income is lower in 1930-40, 1941-50, and 1951-60 by 2.3 percent, 2.2 percent, and 3.0 percent, respectively.

Three percent neutral increase in technology. In Simulation XIV the production function intercept is increased by 3.0 percent per year. Changes mentioned above for the 1.0 percent neutral increase in technology are magnified here.

For 1951-60 the total farm labor force is 46,000 higher than in Simulation I. The rise in labor input is a small proportion, 0.7 percent, of the total farm labor force. Output is 2.8 percent higher, prices received are 13 percent lower, and gross farm income is reduced by 10 percent.

One percent neutral decrease in technology. The assumption implied in Simulation XV is not that there was a net decrease in technology, but that the rate of adoption was 1.0 percent lower than that actually experienced from 1930-60. The question to be answered is whether farmers in general would have benefitted from a lower rate of adoption of new technology.

While the 1.0 percent decrease is not presumed to be large enough to remove the effects of adoption of better farming practices, it does show the direction of changes that could have been expected. Output is 1.0 percent lower in 1951-60 than was estimated in Simulation I. Prices are 4.0 percent higher, and gross income is increased by 2.0 percent ($954 million). Farm labor force numbers decrease by 15,000 workers.

Summary of changes in neutral technology. Results of the preceding three simulations serve to substantiate the part that technology has played in causing surplus agricultural production. The analysis is incomplete, however, because the model incorporates effects that cannot be removed by the simple assumption of neutral technological change. Increases in productivity are unlikely to be neutral, affecting all inputs alike, but rather tend to be associated with specific inputs. Changes in farm size and numbers and attendant changes in machinery use and expenditures remain hidden. The effect on nonfarm firms that have benefitted from the sale of improved production inputs is likewise obscured.

Total net returns to family labor are over 40 percent higher with a 1.0 percent decrease in technology than with a 3.0 percent increase in technology. Net returns per family worker are higher by 43 percent. Thus the results are consistent with the hypothesis that farmers have experienced a relative decline in income as a consequence of technological change.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The overall objective of this study is the analysis of the effect of changes in selected variables on agricultural output, income, and resource use. Past and present involvement of the government in areas relating to agricultural production and resource use indicates the need for more knowledge of the productivity of resources used in agriculture and the manner in which agriculture is influenced by the nonfarm economy.

Procedure

The study is organized into three major sections. Estimation of production elasticities for nine categories of agricultural inputs and specification of an agricultural production function comprises the first section. The next step in the procedure is construction of an aggregate economic model depicting agricultural decision-making, production, and disposition of farm output, together with estimation of coefficients in the model. Simulation of the recursive economic model over the 1930-60 period with selected changes in data and parameters is the final step and describes the long-run or cumulative effects of the conditions under study.

In Chapter III, estimates of the elasticities of production for nine major agricultural input categories were developed. An adjustment model which specifies that the annual adjustment in use of a factor (input) is some portion of the divergence from equilibrium use was assumed. In equilibrium the factor share (ratio of expenditure on a factor to value of final product) is equal to the elasticity of production. Estimates of the elasticity of production were derived from the distributed lag adjustment model using calculated factor shares in a disequilibrium situation by least squares and autoregressive least squares techniques.

Estimates of production elasticities then became the coefficients in a Cobb-Douglas type production function. This function provided the medium by which decisions relating to input use were transformed into estimates of aggregate farm output--in essence the input decision equations and the production function specify an implicit supply function.

Behavioral equations, input demand equations, and an equation for each of (1) commercial market quantity, (2) aggregate demand, and (3) gross farm income are specified and coefficients estimated in Chapter IV. Simulation of the economic model is explained early in Chapter V, followed by presentation of the results of the simulated conditions.

Results and Implications

The results of 15 simulations are presented in this study. Conditions simulated cover: (1) the omission of government diversions of excess production, payments to farmers, and acreage controls; (2) higher support of prices farmers receive; (3) tighter acreage controls; (4) variations in national unemployment and disposable income; (5) higher prices of inputs; (6) changes in production elasticities; and (7) different rates of adoption of technology.

Several implications of the results of the various simulations are consistent with a priori expectations. Removal of government programs for surplus diversion, government payments to farmers, and acreage controls indicated that prices and incomes would have been significantly lower in their absence. Simulation of the model with tighter acreage controls likewise resulted in depressed prices and gross income--and decreases in the efficiency of resource use were apparent.

The level of economic activity in the nonfarm sector has a strong influence on the farm economy. Under conditions of prosperity in the nonfarm sector, as exemplified by full employment and higher disposable income, farm incomes showed significant increases. The reverse effect was obtained when depression conditions in the nonfarm sector were simulated. Consequently, fiscal and monetary policies to maintain and increase national prosperity are also consistent with higher returns for agriculture. Nor does inflation depress farm income as much as anticipated. Higher input prices lead to reductions in inputs and hence output. The result, ceteris paribus, is that farmers in time are able to accommodate to higher input prices by getting more for what they sell.

Variation of production elasticities did not change the results obtained in the original model sufficiently to cause concern--most changes were of less than one percent in magnitude. The assumption of different rates of adoption of technology, however, did affect the estimates. Because technology has generally been output-increasing, a high rate of adoption was seen to disadvantage the income position of farmers.

The results of this study indicate that past programs such as removal of excess production from the commercial market, direct payments to farmers, and long-term acreage removal programs have maintained prices and incomes above the level they would have been otherwise. Higher incomes (and higher land values) have led to substitution of capital for farm workers and to the withdrawal of excess labor from agriculture. Also, simulation of different conditions in the nonfarm sector show the benefit of national prosperity to incomes in agriculture.

Limitations

All value series were deflated to a constant-dollar basis to correct for changes in the general price level. Gross income used in estimating production elasticities was adjusted for interfarm sales of feed, seed, and livestock, as was the feed, seed, and livestock input series. Data used were accepted as the best available, though limitations of concepts and collection methods are pointed out by most data sources. Differences in labor data series published by the U. S. Department of Agriculture and the U. S. Department of Labor were mentioned as an example. The above comments emphasize the need for (1) clarity in referencing of sources and adjustments, and (2) careful consideration by the reader of assumptions stated and procedures employed.

Production elasticity estimates were held constant for ten-year periods, although individual elasticities likely change from year to year. This fact led to discussion of results in average terms, rather than by individual years.

The aggregate economic model used in the simulation procedure is one of many possible formulations. Alternative formulations of the model and individual equations may considerably improve the estimates generated. The machinery purchase equation provides an example--machinery purchases in the model are related only to gross farm income. Although the effects of rising or falling income are taken into account and implicitly prices received by farmers, the price of machinery is not included. The omission results from nonsignificant coefficients estimated for this variable. Exclusion of machinery price also reduces the effectiveness of the simulation in which input prices were increased.

The degree of aggregation in the model is another limitation. Agriculture is treated as a homogeneous industry, when differences in farm size and farming regions may significantly violate the homogenity assumption. A final consideration is the relatively small number of simulations performed. Simulation analysis of alternative hypotheses could add to knowledge of the operation of the agricultural economy.

Suggestions for Further Research

This study has attempted to illustrate the effects of different levels of selected variables on farm resource use, output, prices received, and income for an historical period. The procedures followed appear to be promising for extensions to predictive analysis. Extrapolation of basic variables would be necessary, which raises questions of the accuracy obtained. However, once the basic framework of the model is decided upon, computer simulation is a rapid process--enabling the simulation of the model under many alternative assumptions or conditions.[1]

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[1] Simulation runs presented in this study for a 31-year period required only three minutes on the IBM-7040 computer.

Simulation as a research technique in agricultural economics has the advantages of ease of handling of time lags and non-linearities which may seriously complicate the estimation of multi-equation systems using other techniques. In addition, no norms or goals need by specified. Finally, the ability of the researcher to derive cumulative or long-run results from an economic model adds much to the appeal of the procedure.

The results point to hypotheses that need additional study: (1) that farmers in fact adjust quite rapidly to their concept of the desired or equilibrium, but that this desired or subjective equilibrium is not a general equilibrium in terms of complete national efficiency--or the equilibrium as viewed by farmers includes a considerable discount for the farm way of life or the inadequate preparation of farmers for non-farm jobs, and (2) that the farming industry is able to compensate for inflation-induced input purchases and output that subsequently lead to higher prices received. A third hypothesis supported by this simulation study is that government commodity programs have had a net tendency to reduce farm labor and population. These are challenging issues that require more research.

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APPENDICES

APPENDIX A, TABLE I

DATA USED IN CALCULATING FACTOR SHARES, U. S. AGRICULTURE, 1910-61

Year	FL[a]	FSL[b]	L[c]	M[d]	RE[e]	FOE[f]	MIS[g]	INT[h]	RET[i]	AGFI[j]
	Million Current Dollars									
1910	152	161	--	277.9	2,529	52	558	377	166	7,169
1911	168	134	--	299.8	2,600	61	587	336	183	6,454
1912	161	167	--	325.9	2,730	72	606	374	191	7,699
1913	175	172	--	344.4	2,797	83	633	377	218	7,107
1914	195	175	--	361.3	2,849	91	648	384	222	7,619
1915	165	175	--	390.7	2,928	107	639	412	243	7,882
1916	193	215	--	437.3	3,110	139	715	479	260	8,667
1917	232	252	--	541.6	3,371	198	863	714	292	13,398
1918	311	440	--	713.6	3,706	279	1,024	855	311	14,974
1919	358	427	--	760.5	4,082	328	1,143	945	393	15,941
1920	390	478	--	842.7	4,937	396	1,263	891	483	15,219
1921	249	290	--	794.4	4,473	358	1,048	541	510	9,211
1922	234	284	--	667.4	4,094	331	1,021	524	509	10,087
1923	263	327	--	687.1	4,035	341	1,019	574	516	11,167
1924	264	440	--	727.4	3,894	369	1,019	576	511	11,144
1925	299	408	--	736.5	3,776	433	1,008	602	517	12,934
1926	298	396	--	759.3	3,688	500	1,017	565	526	12,230
1927	267	406	--	795.1	3,609	499	965	545	545	12,029
1928	318	459	--	797.2	3,560	533	971	580	556	12,453
1929	300	437	3,992	804.7	3,610	562	965	593	567	12,665

APPENDIX A, TABLE I (Continued)

Year	FL[a]	FSL[b]	L[c]	M[d]	RE[e]	FOE[f]	MIS[g]	INT[h]	RET[i]	AGFI[j]
	Million Current Dollars									
1930	297	363	3,815	827.2	3,504	547	879	492	567	10,249
1931	202	218	3,031	773.4	3,124	465	796	343	526	8,245
1932	118	179	2,351	664.0	2,614	418	689	279	461	6,040
1933	120	191	2,173	572.8	2,195	405	628	316	398	6,261
1934	176	233	2,349	550.3	2,212	442	623	368	384	6,569
1935	188	267	2,723	576.5	2,203	476	605	371	392	9,110
1936	261	369	2,912	618.7	2,203	513	613	450	394	8,812
1937	279	411	3,318	700.4	2,232	587	675	417	405	10,889
1938	258	342	3,379	746.5	2,208	606	660	389	400	8,998
1939	273	423	3,482	730.8	2,162	610	687	398	407	8,945
1940	306	548	3,664	738.7	2,144	656	708	422	401	9,432
1941	334	609	4,286	790.5	2,221	735	798	549	407	12,386
1942	417	914	5,905	921.8	2,364	835	849	750	399	17,327
1943	505	1,183	7,555	891.4	2,562	1,079	929	1,003	400	20,398
1944	576	1,291	8,834	860.9	2,874	1,225	975	996	419	20,838
1945	657	1,473	9,308	867.4	3,226	1,304	974	1,024	465	21,880
1946	683	1,617	9,670	926.6	3,856	1,456	1,194	1,141	519	25,960
1947	755	2,030	10,227	1,201.7	4,376	1,776	1,426	1,323	605	28,669
1948	826	2,269	10,273	1,678.0	4,737	2,117	1,580	1,273	656	32,492
1949	895	1,835	10,199	2,258.1	4,744	2,266	1,696	1,200	706	27,511

APPENDIX A, TABLE I (Continued)

Year	FL[a]	FSL[b]	L[c]	M[d]	RE[e]	FOE[f]	MIS[g]	INT[h]	RET[i]	AGFI[j]
	Million Current Dollars									
1950	978	2,042	8,620	2,684.1	4,779	2,311	1,750	1,218	741	29,238
1951	1,085	2,564	8,826	3,167.9	5,507	2,535	2,709	1,473	773	33,635
1952	1,229	2,559	8,877	3,432.9	6,061	2,702	2,117	1,429	804	33,380
1953	1,245	2,164	8,764	3,540.8	6,098	2,734	2,100	1,309	839	30,945
1954	1,274	2,224	8,563	3,630.7	6,029	2,702	2,076	1,257	870	30,311
1955	1,256	2,200	9,113	3,618.2	6,345	2,789	2,167	1,210	928	29,653
1956	1,241	2,241	9,350	3,703.6	6,473	3,005	2,303	1,234	977	29,675
1957	1,280	2,325	9,145	3,780.2	6,782	3,164	2,286	1,216	1,044	29,891
1958	1,338	2,670	8,654	3,887.3	7,273	3,217	2,436	1,347	1,103	32,572
1959	1,449	2,806	8,974	4,021.4	7,894	3,341	2,633	1,352	1,187	31,655
1960	1,462	2,788	9,048	4,033.8	8,249	3,283	2,739	1,340	1,284	32,459
1961	1,502	2,989	8,829	3,962.9	8,498	3,186	2,833	1,362	1,361	33,001

[a] Expenditures for fertilizer and lime. From Farm Income Situation, July, 1962 and later issues.

[b] Expenditures for feed, seed, and livestock. Expenditures for each series (from Farm Income Situation) were deflated by their respective indices of prices paid by farmers (from Farm Cost Situation) and summed for each year. The ratio of this sum to the constant dollar sum adjusted for interfarm sales (from worksheets of the Production Adjustments Branch, ERS) was formed. This ratio was used as a factor to convert the Farm Income Situation total in each year (undeflated) to a series in current dollars adjusted for interfarm sales.

[c] Labor expense. To obtain total labor expense (with family and operator labor priced at the hired labor wage rate) the Agricultural Marketing Service (AMS) series "wages paid hired labor" in current dollars was multiplied by the ratio of "total farm labor force" to "hired farm labor force" (all from Agricultural Handbook 118 to 1950; from Farm Income Situation thereafter). This figure was then deflated by the ratio of "CPS

labor force" (from Employment and Earnings) to "AMS labor force." CPS data only cover the period 1929 to date.

[d] Machinery investment expense. Farm power and machinery input series minus miscellaneous farm machinery inputs (fuel, oil, electricity, blacksmith, harness, hand tools) minus license, insurance, repairs, parts, and tires (all in 1947-49 dollars from worksheets, Production Adjustments Branch, ERS) inflated to current dollars using index of prices paid for farm machinery, 1947-49 = 100.

[e] Real estate expense. The value of real estate (from Agricultural Finance Review) times the interest rate on farm mortgage debt, plus building depreciation, accident damage, repairs, and maintenance (from Farm Income Situation).

[f] Fuel, operation, and repairs of machinery. From Farm Income Situation.

[g] Miscellaneous current operating expense. From Farm Income Situation.

[h] Crop and livestock inventory expense. Interest on crop inventories series in 1947-1949 dollars (from worksheets, Production Adjustments Branch, ERS) inflated to current dollars by index of prices received by farmers for all crops; plus interest on livestock inventories series in 1947-49 dollars (from worksheets, Production Adjustments Branch, ERS) inflated to current dollars using index of prices received by farmers for livestock and livestock products.

[i] Real estate taxes expense. From worksheets, Production Adjustments Branch, ERS.

[j] Adjusted gross farm income. Gross farm income less government payments (from Farm Income Situation) less interfarm sales of feed, seed, and livestock.

APPENDIX A, TABLE II

DATA USED IN ESTIMATING COEFFICIENTS FOR THE SIMULATION MODEL (EXCLUDING PRODUCTION ELASTICITIES)

Year	AC[a]	SP[b]	PF[c]	PR[d]	CLI[e]	OUT[f]	GFI[g]
1929	379	94,913	133.8	80.9	17,341.7	20,306.0	20,254
1930	382	97.633	134.8	70.4	17,201.3	19,789.2	17,095
1931	384	99,463	138.4	55.4	16,916.8	21,595.8	15,303
1932	384	95,966	133.6	45.8	18,566.1	20,979.0	12,368
1933	378	85,871	127.5	51.0	19,590.1	19,389.0	13,504
1934	375	83,100	134.2	60.7	18,531.5	16,523.0	13,991
1935	377	82,425	135.9	74.5	15,038.8	19,913.1	19,300
1936	375	84,414	121.9	75.3	17,214.7	17,830.3	17,753
1937	379	83,730	127.4	79.6	15,128.0	22,525.0	21,496
1938	372	86,447	125.7	63.7	17,538.4	21,747.0	18,110
1939	363	85,978	125.4	62.7	18,071.5	21,997.0	19,088
1940	368	85,249	122.1	65.5	18,535.4	22,825.4	20,034
1941	367	82,355	111.5	74.3	19,264.6	23,646.6	23,018
1942	370	82,414	108.4	84.2	20,467.9	26,544.2	28,340
1943	377	85,406	105.3	92.3	22,271.2	26,142.2	30,311
1944	379	92,248	106.1	93.4	22,337.7	26,846.6	30,693
1945	372	97,244	104.6	94.6	21,790.3	26,415.9	31,548
1946	369	101,151	99.2	101.5	21,263.6	27,120.7	34,697
1947	373	101,302	97.0	106.4	20,932.7	26,216.6	33,985
1948	378	102,073	100.6	104.4	19,302.7	28,704.0	36,140
1949	387	106,920	102.2	89.6	20,959.2	28,136.9	30,144
1950	377	106,246	97.7	91.9	20,587.1	27,957.7	32,202
1951	381	112,401	94.5	99.8	21,190.0	28,832.3	34,313
1952	380	119,519	95.4	92.7	21,684.7	29,889.9	33,191
1953	380	120,440	95.2	82.2	22,213.9	30,111.9	29,969
1954	380	119,052	94.6	79.1	22,220.1	30,177.9	29,540
1955	378	121,653	92.3	73.5	22,610.7	31,232.0	28,743
1956	369	123,673	87.7	70.4	23,163.2	31,590.9	28,320
1957	358	125,841	85.5	69.5	22,607.2	31,504.9	28,076
1958	355	129,181	83.7	71.9	23,481.8	34,378.1	30,352
1959	358	135,550	81.5	68.5	24,601.8	34,583.2	28,901
1960	355	138,025	80.2	66.6	24,571.9	35,384.7	28,965

APPENDIX A, TABLE II (Continued)

Year	PUR[h]	PNF[i]	SM[j]	PRE[k]	TFLF[l]	VRE[m]	U[n]
1929	1,030	69.9	4,450.2	101.8	10,450	70,541.2	3.2
1930	819	67.8	4,647.8	104.1	10,340	73,312.4	8.7
1931	494	68.5	4,587.5	105.9	10,290	75,657.4	15.9
1932	266	62.1	4,252.0	97.7	10,170	70,954.2	23.6
1933	241	62.6	3,722.5	82.2	10,090	60,396.1	24.9
1934	528	64.3	3,278.4	80.7	9,900	59,193.0	21.7
1935	723	71.2	3,258.0	84.7	10,110	61,944.1	20.1
1936	979	74.3	3,393.9	85.1	10,000	61,397.8	16.9
1937	1,109	80.9	3,771.2	87.3	9,820	62,323.9	14.3
1938	777	75.1	4,127.8	88.0	9,690	62,247.8	19.0
1939	863	81.5	4,074.8	87.3	9,610	61,084.2	17.2
1940	977	84.8	4,181.0	86.2	9,540	59,532.7	14.6
1941	1,429	91.4	4,352.9	79.5	9,100	55,573.5	9.9
1942	1,364	100.6	4,946.5	75.9	9,250	53,562.1	4.7
1943	908	107.8	4,957.2	75.8	9,080	54,101.4	1.9
1944	1,608	112.2	4,534.6	85.5	8,950	61,636.8	1.2
1945	1,566	105.7	4,557.7	92.2	8,580	67,103.4	1.9
1946	1,322	97.2	4,777.2	97.7	8,320	71,232.2	3.9
1947	2,220	98.4	5,031.6	97.6	8,256	71,390.0	3.9
1948	2,737	100.7	6,090.7	99.8	7,960	72,646.9	3.8
1949	2,675	100.8	7,400.8	102.4	8,017	74,608.6	5.9
1950	2,598	108.3	8,734.2	99.9	7.497	72,781.4	5.3
1951	2,512	108.5	9,706.5	106.3	7,048	77,171.1	3.3
1952	2,173	112.8	10,417.3	114.7	6,792	83,182,9	3.1
1953	2,278	117.2	10,617.5	115.2	6,555	83,507.8	2.9
1954	1,944	116.5	10,950.2	113.0	6,495	81,718.0	5.6
1955	1,978	124.4	10,908.1	116.8	6,718	83,907.7	4.4
1956	1,677	125.3	10,870.6	117.5	6,572	85,210.3	4.2
1957	1,663	125.3	10,556.0	120.7	6,222	88,195.7	4.3
1958	2,121	124.2	10,280.5	123.9	5,844	90,644.3	6.8
1959	1,922	130.5	10,340.6	130,8	5,836	95,686.9	5.5
1960	1,591	130.7	10,201.8	133.8	5,723	98,356.5	5.6

APPENDIX A, TABLE II, (Continued)

Year	PMS[o]	PFS[p]	POP[q]	YD[r]	CPI[s]	GP[t]	TAX[u]
1929	130.9	107.4	121.8	1,002.9	107.8	0	120
1930	128.6	110.3	123.1	925.0	109.3	0	131
1931	124.6	114.2	124.0	889.3	112.5	0	143
1932	135.5	110.7	124.8	774.3	111.5	0	152
1933	135.3	105.9	125.6	713.7	108.4	256.9	125
1934	136.0	104.8	126.4	755.1	105.1	819.9	117
1935	135.9	106.1	127.2	852.9	122.7	1,067.0	114
1936	132.6	103.9	128.1	924.7	119.2	498.2	111
1937	134.5	108.0	128.8	975.2	121.9	594.7	115
1938	132.7	109.7	129.8	895.6	123.2	789.4	117
1939	130.8	109.3	130.9	962.4	123.8	1,367.4	121
1940	125.7	109.7	132.1	1,019.5	122.8	1,279.6	118
1941	119.5	106.6	133.4	1,126.0	115.3	878.8	112
1942	112.7	104.1	134.9	1,242.5	109.0	927.2	97
1943	105.3	106.6	136.7	1,269.2	102.1	838.8	84
1944	104.9	110.0	138.4	1,356.8	104.3	992.3	79
1945	102.1	108.3	139.9	1,338.7	103.9	924.0	77
1946	98.0	102.7	141.4	1,325.6	101.6	900.8	77
1947	95.9	99.1	144.1	1,230.4	99.2	327.4	83
1948	101.6	98.6	146.6	1,273.2	100.6	253.5	87
1949	102.2	102.2	149.2	1,238.6	100.3	181.1	95
1950	102.5	101.5	151.7	1,324.0	100.9	273.7	100
1951	98.9	99.8	154.3	1,314.6	98.8	254.0	91
1952	98.0	104.1	156.9	1,330.7	99.4	240.6	86
1953	98.6	100.3	159.6	1,368.5	100.2	184.3	89
1954	99.7	96.3	162.4	1,360.3	100.1	221.0	93
1955	100.0	94.0	165.3	1,418.8	99.8	195.7	96
1956	98.5	91.9	168.2	1,441.2	98.3	458.6	96
1957	99.0	88.7	171.3	1,440.1	98.1	811.5	94
1958	96.2	87.6	174.2	1,426.9	98.2	851.4	95
1959	95.4	85.4	177.1	1,464.6	98.5	524.6	94
1960	94.6	84.0	180.7	1,466.3	98.5	524.6	97

APPENDIX A, TABLE II (Continued)

Year	CMQ[v]	HC[w]	CIF[x]	GD[y]	ADIV[z]
1929	18,000.0	2,117.4	-150.8	0	0
1930	17,966.8	2,204.5	-382.1	0	0
1931	18,482.1	2,283.4	830.3	0	0
1932	18,570.7	2,168.1	240.2	0	0
1933	17,727.6	2,019.6	-380.4	22.2	0
1934	16,182.4	1,853.4	-1,532.1	19.3	0
1935	17,024.7	1,771.8	936.9	179.7	0
1936	17,046.7	1,851.3	-1,070.4	2.7	0
1937	19,264.9	1,801.5	1,025.1	433.5	0
1938	19,279.6	1,938.8	207.2	321.4	0
1939	19,656.0	1,928.2	151.5	261.3	0
1940	20,418.7	1,847.3	429.0	130.4	0
1941	20,999.2	1,923.3	565.3	158.8	0
1942	22,983.5	2,087.9	1,305.2	167.6	0
1943	23,648.5	2,441.0	-56.3	109.0	0
1944	24,792.2	2,335.1	-439.0	158.3	0
1945	24,388.9	2,490.5	-464.1	0.6	0
1946	24,303.6	2,787.2	28.6	1.3	0
1947	25,067.8	2,792.3	-1,654.1	10.6	0
1948	23,014.0	2,799.0	1,657.4	1,233.6	0
1949	24,919.8	2,677.5	-96.3	635.9	0
1950	25,315.7	2,418.9	886.8	663.7	0
1951	25,076.2	2,476.0	1,178.3	101.8	0
1952	24,381.1	2,560.9	993.5	1,954.4	0
1953	25,828.9	2,629.0	-755.5	2,409.5	0
1954	25,501.3	2,457.6	619.5	1,599.5	0
1955	26,517.9	2,457.1	404.1	1,852.9	0
1956	28,217.0	2,521.3	-589.5	1,442.1	0.714
1957	26,746.6	2,535.3	1,086.4	1,126.6	3.214
1958	29,644.6	2,158.6	1,269.8	1,305.1	4.943
1959	31,548.4	1,938.7	134.3	961.8	11.232
1960	32,704.9	1,884.4	494.0	301.4	14.330

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[a] AC: millions of acres of cropland used for crops. U. S. Department of Agriculture, Changes in Farm Production and Efficiency, Statistical Bulletin 233, (Washington, July 1964), pp. 15-16.

APPENDIX A, TABLE II (Continued)

[b] SP: stock of productive assets in million 1947-49 dollars as of January 1 (includes machinery, crops, livestock and estimates of cash for productive purposes). From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

[c] PF: index of prices paid by farmers for fertilizer material. 1910-14=100 index (*Agricultural Prices*, September, 1964, p. 55) converted to 1947-49=100 and deflated by implicit GNP price deflator (1954=100 index, *Economic Report of the President*, January, 1965, p. 196, converted to 1947-49=100).

[e] CLI: inventory of crops and livestock on farms in million 1947-49 dollars as of January 1. From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

[f] OUT: farm output in million 1947-49 dollars. From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

[g] GFI: total gross farm income in million 1947-49 dollars (including government payments). Current dollar series (*Farm Income Situation*, July, 1964, p. 46) deflated by implicit GNP price deflator (1954=100 index, *Economic Report of the President*, January, 1965, p. 196, converted to 1947-49=100).

[h] PUR: purchases of machinery in million 1947-49 dollars. Current dollar series (*Farm Income Situation*, July, 1964, p. 54) deflated by index of prices paid for farm machinery (1910-14=100 index, *Agricultural Prices*, September, 1964, p. 55, converted to 1947-49=100).

[i] PNF: index of average annual wage of production workers in manufacturing (1947-49=100). From *Farm Income Situation*.

[j] SM: stock of machinery in million 1947-49 dollars. From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

[k] PRE: index of average per acre value of farm real estate, 1947-49=100 (*Agricultural Finance Review*, December, 1963, p. 60) deflated by implicit GNP price deflator (1954=100 index, *Economic Report of the President*, January, 1965, converted to 1947-49=100).

[l] TFLF: total farm labor force in 1000's. From *Employment and Earnings*, Vol. 10, No. 12, U. S. Department of Labor.

[m] VRE: value of farm real estate in million 1947-49 dollars. Current dollar series (*Agricultural Finance Review*, December, 1963, p. 61) deflated by implicit GNP price deflator 1954=100 index, *Economic Report of the President*, January, 1965, p. 196, converted to 1957-49=100).

APPENDIX A, TABLE II (Continued)

[n] U: unemployment percentage. From *Economic Report of the President*, January, 1965, p. 214.

[o] PMS: index of prices paid for motor supplies. 1910-14=100 index (*Agricultural Prices*, September, 1964, p. 55) converted to 1947-49=100 and deflated by implicit GNP price deflator (1954=100 index, *Economic Report of the President*, January, 1965, p. 196, converted to 1947-49=100).

[p] PFS: index of prices paid for farm supplies. 1910-14=100 index (*Agricultural Prices*, September, 1964, p. 55) converted to 1947-49=100 and deflated by implicit GNP price deflator (1954=100, *Economic Report of the President*, January, 1954, p. 196, converted to 1947-49=100).

[q] POP: United States population (millions). From *Economic Report of the President*, January, 1965, p. 213.

[r] YD: per capita disposable income in 1947-49 dollars. Current dollar series deflated by implicit GNP price deflator (1954=100 index converted to 1947-49=100). Income series and index from *Economic Report of the President*, January 1965, p. 209 and p. 196.

[t] GP: government payments to farmers in million 1947-49 dollars. Current dollar series (*Farm Income Situation*, July, 1964, p. 46) deflated by implicit GNP price deflator (1954=100 index, *Economic Report of the President*, January, 1965, p. 196, converted to 1947-49=100).

[u] TAX: real estate tax rate in dollars per $10,000 valuation from *Agricultural Finance Review*, December, 1963, p. 51.

[v] CMQ: commercial market quantity in million 1947-49 dollars, defined as equal to output (OUT) minus the sum of home consumption (HC), change in inventories on farms (CIF), and government diversions (GD).

[w] HC: home consumption in million 1947-49 dollars. Series in current dollars from *Farm Income Situation* (July, 1965, p. 47) deflated by implicit GNP price deflator.

[x] CIF: change in inventories on farms in million 1947-49 dollars. Series in current dollars (from *Farm Income Situation*, July, 1965, deflated by index of price received (1947-49=100).

[y] GD: government (CCC) diversions in million 1947-49 dollars. Data since 1948 are from Hathaway and Stollsteimer, and Tyner and Tweeten (1964), deflated by the implicit gross national product price deflator. Data for 1932-47 are calculated as the value (based on average prices received by farmers) of (1) acquisition of commodities pledged as collateral for price support loans and (2) purchased from processors or handlers, or from producers by purchase agreements by CCC, minus the value of domestic dispositions by CCC in the same year. Commodities included are corn, cotton, tobacco, wheat, rice, rye, grain sorghum, barley, oats, peanuts, and

APPENDIX A, TABLE II (Continued)

dairy products. The data sources and calculation procedures are explained in Tyner and Tweeten (1964).

[z] ADIV: millions of acres diverted by acreage control programs. Data for 1961-64 are 39.471, 51.813, 43.820, and 46.341. ADIV is calculated as the sum of cropland diverted under the feed grain and wheat programs, plus one-half of the Conservation Reserve acres. See U. S. Department of Agriculture, Farm Production--Trends, Prospects, and Programs, Washington: 1961, p. 36.

APPENDIX A, TABLE III

DATA USED FOR CALCULATING THE PRODUCTION FUNCTION INTERCEPTS

Year	FL[a]	FSL[b]	L[c]	M[d]	RE[e]	FOE[f]	MIS[g]	INT[h]	RET[i]
1929	292.8	782.3	23,158	1,257.3	3,471.5	631.5	1,321.9	1,077.2	877.2
1930	298.0	758.9	22,921	1,292.5	3,404.8	651.2	1,220.8	1,068.3	928.7
1931	230.0	654.0	23,427	1,237.7	3,337.7	645.8	1,206.1	1,050.6	1,002.0
1932	155.0	692.5	22,605	1,125.4	3,248.6	588.7	1,187.9	1,153.3	1,025.8
1933	172.7	705.1	22,554	987.6	3,268.3	587.0	1,163.0	1,217.0	905.0
1934	206.3	663.4	20,232	917.2	3,250.7	597.3	1,093.0	1,150.6	792.1
1935	238.9	643.5	21,052	929.8	3,323.9	652.1	1,061.4	938.5	784.2
1936	282.9	877.2	20,440	982.1	3,334.2	693.2	1,056.9	1,068.0	788.1
1937	332.6	831.8	22,097	1,094.3	3,376.0	772.4	1,106.6	939.2	764.4
1938	316.4	863.9	20,577	1,131.1	3,393.8	808.0	1,064.5	1,089.4	800.0
1939	336.4	1,063.0	20,675	1,124.3	3,426.7	835.6	1,126.2	1,122.7	821.8
1940	393.0	1,286.5	20,472	1,154.2	3,485.1	911.1	1,141.9	1,151.2	802.0
1941	430.2	1,330.2	20,046	1,216.1	3,458.7	993.2	1,209.1	1,196.6	768.0
1942	482.6	1,639.1	20,583	1,336.0	3,419.2	1,120.3	1,163.0	1,271.3	654.0
1943	541.6	1,793.4	20,297	1,255.5	3,348.2	1,332.1	1,132.9	1,411.3	588.0
1944	619.2	1,829.6	20,163	1,179.3	3,289.7	1,493.9	1,133.7	1,394.1	574.0
1945	640.7	2,063.0	18,838	1,172.1	3,282.8	1,590.2	1,119.5	1,353.4	612.0
1946	757.3	1,971.8	18,080	1,219.2	3,413.7	1,733.3	1,356.8	1,320.7	625.0
1947	799.5	2,075.2	17,196	1,381.3	3,479.6	1,930.4	1,501.1	1,300.2	630.0
1948	811.3	2,072.5	16,833	1,678.0	3,567.5	2,055.3	1,564.4	1,198.8	631.0
1949	865.1	1,980.3	16,202	1,998.3	3,588.7	2,158.1	1,615.2	1,302.1	706.0
1950	977.4	2,073.0	15,137	2,313.9	3,651.1	2,159.8	1,666.7	1,278.9	726.5

APPENDIX A, TABLE III (Continued)

Year	FL[a]	FSL[b]	L[c]	M[d]	RE[e]	FOE[f]	MIS[g]	INT[h]	RET[i]
1951	1,039.8	2,286.6	15,222	2,534.3	3,674.3	2,263.4	1,856.3	1,316.2	684.1
1952	1,150.8	2,309.2	14,504	2,661.2	3,727.3	2,412.5	1,779.0	1,346.8	699.1
1953	1,180.1	2,281.6	13,966	2,723.7	3,722.8	2,377.4	1,810.3	1,379.7	755.9
1954	1,255.5	2,356.4	13,310	2,771.5	3,758.3	2,329.3	1,853.6	1,380.1	783.8
1955	1,283.6	2,440.0	12,808	2,762.0	3,756.9	2,383.8	1,970.0	1,404.4	843.6
1956	1,306.6	2,606.3	12,028	2,723.2	3,718.4	2,504.2	2,074.8	1,438.8	880.2
1957	1,341.4	2,646.6	11,059	2,643.5	3,726.9	2,551.6	2,041.1	1,404.2	915.8
1958	1,378.1	2,875.6	10,548	2,608.9	3,745.4	2,615.4	2,175.0	1,458.8	942.7
1959	1,557.4	3,033.7	10,301	2,577.8	3,756.8	2,694.4	2,350.9	1,528.4	997.5
1960	1,567.2	3,113.2	9,825	2,521.1	3,749.6	2,626.4	2,445.5	1,526.4	1,079.0

[a] FL: Expenditures for fertilizer and lime in million 1947-49 dollars. From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

[b] FSL: Purchases of feed, seed, and livestock from the non-farm sector (essentially marketing charges) in million 1947-49 dollars. From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

[c] L: Million man-hours of labor used for farm work. From _Changes in Farm Production and Efficiency_, Statistical Bulletin 233, ERS, U. D. Department of Agriculture, revised July, 1964.

[d] M: Charges in million 1947-49 dollars for interest on investment in machinery, plus depreciation. From worksheets, Production Adjustments Brnach, ERS, U. S. Department of Agriculture.

[e] RE: Charges in million 1947-49 dollars for interest on investment in real estate, plus building depreciation, accident damage, repairs, and maintenance. From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

APPENDIX A, TABLE III (Continued)

[f] FOE: Charges for fuel, operation, and repairs of machinery in million 1947-49 dollars. Current dollar series (from Farm Income Situation, July, 1964) deflated using index of prices paid for motor supplies (1947-49 = 100).

[g] MIS: Miscellaneous current operating expenses in million 1947-49 dollars. Current dollar series (from Farm Income Situation, July, 1964) deflated using index of prices paid for farm supplies (1947-49 = 100).

[h] INT: Charges for interest on crop and livestock inventories in million 1947-49 dollars. From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

[i] RET: Real estate taxes in million 1947-49 dollars. From worksheets, Production Adjustments Branch, ERS, U. S. Department of Agriculture.

APPENDIX B

FORTRAN STATEMENTS FOR SIMULATION PROGRAM

```
C       ORIGINAL MODEL (SIMULATION I)
        DIMENSION G(31,28)
C       READ G
      1 FORMAT(8F10.3)
C       READ 1929 START
      2 FORMAT(8F10.3)
C       WRITE PRE- HEADINGS
     30FORMAT(////12X,2HAC,9X,3HCLI,8X,4HCLIM,10X,2HSP,9X,3HSPM,9X,3HPUR,
      19X,3HPRE,9X,3HVRE,10X,2HSM,9X,3HSMM/)
C       WRITE PRE- OUTPUT
      4 FORMAT(2X,I4,2X,10(F10.2,2X)///)
C       WRITE IN- HEADINGS
     50FORMAT(12X,2HFL,9X,3HFSL,8X,4HTFLF,9X,3HXLT,10X,2HXM,10X,2HRE,9X,
      13HFOE,8X,4HXMIS,8X,4HXINT,9X,3HRET/)
C       WRITE IN- OUTPUT
      6 FORMAT(8X,10(F10.1,2X)///)
C       WRITE OUT- HEADINGS
      7 FORMAT(12X,3HOUT,19X,3HCMQ,20X,2HPR,19X,3HGFI/)
C       WRITE OUT- OUTPUT
      8 FORMAT(8X,5(F10.1,12X)///)
C       READ GIVEN DATA (G)-1POPT,2SPT,3PFTM1,4UTM1,5PHTM1,6PMSTM1,7PFSTM1
C       ,8PURTM1,9PMTM1,10YDT,11CPIT,12GPT,13CLIT,14SMT,15NOFTM1,16TXRT,17
C       CIF,18HC,19ADIV,20GD,21(1-5UTM1),22PNFTM1
      9 READ(5,1)G
    701 FORMAT(I2)
    702 FORMAT(8X,I2)
C       READ ALT DATA
        READ(5,701) K
        IF(K.LE.0)GO TO 10
    101 DO 103 J=1,K
        READ(5,702) N
    102 READ(5,1)(G(I,N),I=1,31)
    103 CONTINUE
C       READ 1929 START
     10 READ(5,2)AC,PR,OUT,GFI,PRE,PUR,FL,FSL
        WRITE(6,2)AC,PR,OUT,GFI,PRE,PUR,FL,FSL
C       PRE-INPUT EQS
        KYR=1929
        SAVE1=0.
        CMQ=0.
        SOUT=0.
        SPR=0.
        SGFI=0.
        SFL=0.
        SFSL=0.
        STFLF=0.
        SXM=0.
        SRE=0.
        SFOE=0.
        SXMIS=0.
        SXINT=0.
        SRET=0.
        SINP=0.
```

```
   98 DO 99 I=1,31
      CMQL=CMQ
      KYR=KYR+1
      IF(KYR.GT.1955)GO TO 111
   11 AC=87.57229+.64625*AC+.00003*G(I,2)+.20668*G(I,3)+.23255*PR
      GO TO 12
  1110AC=-161.30628-.92273*G(I,19)+.07881*AC+.00204*G(I,2)+2.67889*G(I,3
     1)+.0069*PR
   12 CLI=5421.775+.34221*OUT-.02922*GFI+.35045*G(I,13)
   13 CLIM=(CLI+G(I,13))/2.0
   14 SP=-2552.222+.30869*GFI+.96046*G(I,2)
   15 SPM=(SP+G(I,2))/2.0
      IF(GFI.LT.SAVE1)GO TO 216
   16 PUR=-529.777+.08058*GFI
      SAVE1=GFI
      GO TO 17
  216 PUR=-1320.563+.10708*GFI
      SAVE1=GFI
   17 PRE=-5.3136+.00042*GFI+.95482*PRE
   18 VRE=-3253.315+754.84551*PRE
   19 SM=-175.0837+.84260*PUR+.86576*G(I,14)
   20 SMM=(SM+G(I,14))/2.0
C     INPUT EQS
   21 FL=584.58328-4.11854*G(I,3)+.88698*FL-.00048*GFI
   22 FSL=-661.442+.04534*CLIM+.88516*FSL
   23 TFLF=11618.758-.41963*SMM-8.2967*G(I,21)*G(I,22)
      YR=KYR
   24 XLT=-4544.288+2.65069*TFLF
   26 XM=121.4768+.23987*SMM
   27 RE=-22556.27+13.22438*YR+.00474*VRE
      IF(KYR-1930)100,228,127
   28 FOE=7732.539-10.17682*AC+.11792*SMM-27.6532*G(I,6)
   29 XMIS=1273.4703+.01771*SPM-15.61617*G(I,7)
   30 XINT=4.4849+.06153*CLIM
      IF(KYR-1930)100,331,230
   31 RET=G(I,16)*VRE/10.0
C     OUTPUT,ETC,EQS
   32 IF(I.LE.12)GO TO 50
   33 IF(I.LE.22)GO TO 51
   34 IF(I.LE.31)GO TO 52
   500OUT=7.64468*(FL**.02648)*(FSL**.06165)*(XLT**.34777)*(XM**.06056)*
     1(RE**.23619)*(FOE**.06513)*(XMIS**.07550)*(XINT**.04587)*(RET**
     2.03861)
      GO TO 53
   510OUT=17.56649*(FL**.02885)*(FSL**.08766)*(XLT**.34458)*(XM**.07768)
     1*(RE**.14837)*(FOE**.06901)*(XMIS**.05133)*(XINT**.04441)*(RET**
     2.02112)
      GO TO 53
   520OUT=7.52389*(FL**.04325)*(FSL**.08862)*(XLT**.28983)*(XM**.09408)*
     1(RE**.23816)*(FOE**.10321)*(XMIS**.07793)*(XINT**.04112)*(RET**
     2.03542)
   53 CMQ=OUT-G(I,18)-G(I,17)-G(I,20)
      IF(KYR-1930)152,152,54
  152 ZMQL=18106.0
```

```
    YDL=1002.9
    CPIL=107.8
    POPL=121.8
   0PR=-44.29011-.01121*CMQ+.05298*G(I,10)+.14582*G(I,11)+.40325643*
   1(PR+.01121*ZMQL-.05298*YDL-.14582*CPIL)+2.2944249*G(I,1)-
   2.9252416*POPL
    GO TO 55
540PR=-44.29011-.01121*CMQ+.05298*G(I,10)+.14582*G(I,11)+.40325643*
   1(PR+.01121*CMQL-.05298*G(I-1,10)-.14582*G(I-1,11))+2.2944249*
   2G(I,1)-.9252416*G(I-1,1)+24.18*G(I,24)
 55 GFI=1805.5666+1.3036*(PR*CMQ/100.)+.35663*G(I,12)
    TINP=FL+FSL+XM+RE+FOE+XMIS+XINT+RET
    SOUT=SOUT+OUT
    SPR=SPR+PR
    SGFI=SGFI+GFI
    SFL=SFL+FL
    SFSL=SFSL+FSL
    STFLF=STFLF+TFLF
    SXM=SXM+XM
    SRE=SRE+RE
    SFOE=SFOE+FOE
    SXMIS=SXMIS+XMIS
    SXINT=SXINT+XINT
    SRET=SRET+RET
    SINP=SINP+TINP
5560IF(KYR.EQ.1940)WRITE(6,6)SFL,SFSL,STFLF,YR,SXM,SRE,SFOE,SXMIS,
5561SXINT,SRET
557 IF(KYR.EQ.1940)WRITE(6,8)SOUT,YR,SPR,SGFI,SINP
 560IF(KYR.EQ.1950)WRITE(6,6)SFL,SFSL,STFLF,YR,SXM,SRE,SFOE,SXMIS,
 561SXINT,SRET
 57 IF(KYR.EQ.1950)WRITE(6,8)SOUT,YR,SPR,SGFI,SINP
 60 WRITE(6,3)
 61 WRITE(6,4)KYR,AC,CLI,CLIM,SP,SPM,PUR,PRE,VRE,SM,SMM
 62 WRITE(6,5)
 63 WRITE(6,6)FL,FSL,TFLF,XLT,XM,RE,FOE,XMIS,XINT,RET
 64 WRITE(6,7)
 65 WRITE(6,8)OUT,CMQ,PR,GFI,TINP
 99 CONTINUE
 58 WRITE(6,6)SFL,SFSL,STFLF,YR,SXM,SRE,SFOE,SXMIS,SXINT,SRET
 59 WRITE(6,8)SOUT,YR,SPR,SGFI,SINP
100 CALL EXIT
    END
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VITA

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Candidate for the Degree of

Doctor of Philosophy

Thesis: A SIMULATION ANALYSIS OF THE ECONOMIC STRUCTURE OF U. S. AGRICULTURE

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