MICHIGAN'S AGRICULTURAL PRODUCTION

By

David L. Watt

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1976

ABSTRACT

MICHIGAN'S AGRICULTURAL PRODUCTION

By

David L. Watt

In the last few years the agricultural sector has experienced significant instabilities. Many of these instabilities and their impacts were not predicted by agriculturalists in the forecasting and projecting business. During the last three decades, citizens, regulatory agencies and legislative bodies have recognized the important influence of government policy on the performance of the agricultural sector. The recent perturbations have led to a recognition of the need for better informational inputs into the policy making process. A comprehensive understanding of the agricultural sector as an integrated system is a prerequisite to this information.

This study focuses on the productive behavior in Michigan's agricultural sector as a reactor to its economic environment. Emphasis is on the physical relationships among inputs and outputs of the sector and farm firm decision behavior. The economic environment was included in the analysis as an exogenous factor. The productive process of the agricultural sector was modeled using Cobb-Douglas production functions in a recursive simultaneous solution programming algorithm.

The purpose of this study was to investigate the physical relationships and behavioral patterns of Michigan's agricultural commodity

production by developing a production component for an existing model of Michigan's agricultural sector. Information used in the modeling process came from a synthesis of previous research on agricultural production. Specific emphasis was given to the synthesizing of information to determine important areas of needed information and to the evaluation of the strengths and weaknesses of the model structure specified in the study.

The simulation model attempted to track the productive behavior of Michigan's agricultural sector from 1955 through 1962. An ad hoc process of adjusting model parameters and behavioral rules was used to optimize model performance. Sector level Cobb-Douglas production functions were estimated for 12 commodities and 1 residual category. Inputs to the sector were disaggregated to 24 separate inputs. Input supply schedules and commodity demand schedules were used by an algorithm which solved for the equating of the value marginal products of inputs with their respective prices. The component was recursively used in each year of run of the sector model to solve for input and output quantities.

Conclusions drawn in this study:

1. A simultaneous equation solving algorithm using Cobb-Douglas production functions and price-quantity schedules market interfaces is feasible for use as a component of a larger model.

2. The validity of the Cobb-Douglas programming component has not been sufficiently tested and cannot be until more accurate data for parameter determination and initial conditions for the model is found

or developed. Specifically, the levels of aggregation in input and output categories necessitated by lack of more detailed information and sheer magnitude of this study seriously impaired the validation of the model.

Implications:

1. The Cobb-Douglas programming algorithm developed appears to have applications far beyond its use in this study. It is adaptable to firm level modeling in addition to a wide variety of sector level, regional and national modeling efforts.

2. The modeling of the physical and behavioral relationships of the agricultural sector to a level of specificity to be useful to decision makers at governmental, business or individual levels requires information from a broad spectrum of sources, including many academic disciplines.

3. The determination of changes in the levels of technology is crucial to model performance. The present model indicates there was a significant transformation in the egg and milk production processes during the 1955 to 1962 time period.

4. The equating of value marginal products of land among crop activities was the best method of modeling the land allocation process derived in this study. But this process did not adequately model differences in land quality allocated to the various crops or the impacts of the federal feed grain and wheat programs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Michigan's agriculture is constantly changing. The changes take place by adaptation of those individuals within agriculture or affected by agriculture. The environment in which agriculture operates is affected and controlled by factors both within and external to the state. Analysis of the present and future environment of agriculture is necessary for initiating and managing the changes which will aid the adaptation process. The welfare of the agricultural sector and the state as a whole is affected by the quality of analysis that take place. Poor analysis can result in mistakes in adaptation that commit resources to uses that do not properly meet the needs of the people of the state. Analytical capabilities are needed both by those within the agricultural sector and those who regulate and make policies which affect it.

In 1964 there was a recognized need for a comprehensive look at the agricultural sector and its future potential through 1980. Project 80, a study by the College of Agriculture and Natural Resources, Michigan State University, partially filled this need. By 1971 the changes in the agricultural sector and its environment were considered significant enough to warrant a complete repeat of the study. This study, called Project 80&5, used much the same format as its predecessor but was significantly improved by the experience gained from the previous study.

Since Project 80 & 5, there have been significant technological and methodological developments in data and information storage and handling, through the use of computers. These developments have been to large studies like Project 80 and 80 & 5.[1] This work has produced methodologies which have greatly reduced the cost of agricultural sector studies.[2]

The realized reductions in cost led to the recognition that a computerized study of Michigan's agricultural sector could have benefits far exceeding its cost. A pilot study which computerized information from Project 80 & 5 was initiated in March, 1974, to investigate the potential of a large computerized modeling effort. The results of the pilot study motivated the submission of a research proposal, entitled "Michigan Agricultural Sector Study" to the Michigan Agricultural Experiment Station. The Michigan Agricultural Experiment Station

---

[1]The major works which have made conceptual and methodological contributions to this study are described in:

Jay W. Forester, World Dynamics, (Cambridge, Massachusetts: Wright-Allen Pres, 1971).

Donella H. Meadows, et al., The Limits To Growth, (New York: Universe Books, 1972).

H. R. Hamilton, et al., Systems Simulation for Regional Analysis: An Application to River-Basin Planning, (Cambridge, Massachusetts: M.I.T. Press, 1969).

Glenn L. Johnson, et al., A Generalized Simulation Approach to Agricultural Sector Analysis: With Special Reference to Nigeria, East Lansing: Michigan State University, 1971).

George E. Rossmiller, et al., Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985, East Lansing: Michigan State University, 1972).

[2]The Computer Library for Agricultural Systems Simulation, a project of the Agricultural Sector Analysis and Simulation Projects at Michigan State University and funded by AID/csd-2975, is in the process of collecting useful components from previous projects. Components from this library have reduced the costs of the model used in this study.

recognized the need for further development of computer-based research and analysis of agricultural sector capabilities, potential, and adaptive strategies by approving the research proposal.

Focus of Study

A study of the magnitude required to construct and maintain a computerized sector model proceeds by segmenting it into manageable pieces which build upon each other. Emphasis is on determining research pieces which are complementary and aggregative. The natural separation of a large model is into its components. The development of an improved production component for the model developed during the pilot study is a manageable venture for agricultural economics project. The inputs and outputs of the agricultural production processes are the important variables to be modeled. Improvement of the production component is the primary focus of this study, although a discussion of the total model and its potential is included.

Objectives

Specifically the objectives of this study are to:

1. Develop a conceptual framework of the structure and characteristics of Michigan's agricultural sector which affect the development of the sector and the decisions made within the sector.

2. Review and analyze previous Michigan agricultural sector research to determine a method of improving the accuracy and usefulness of such research.

3. Improve the present Michigan Agricultural Sector Model by a) specifying an economic model of the production decisions made in Michigan's agricultural sector, b) developing a computerized production

component and, c) inserting the component into the sector model.

4. Evaluate and draw conclusions about the component's ability to reflect the production processes and to track agricultural production in Michigan.

Description of the Study

In this study a production component based on Cobb-Douglas production functions is developed. It determines quantities of inputs used by the sector according to the economic principle of equating input price with value of marginal product. A valuable spin-off of this study is the general adaptability of the developed component in a wide spectrum of applications. It can be used not only in regional and national modeling efforts but also in firm-level management decision-making. It is similar to linear programming but uses Cobb-Douglas instead of linear production functions. Cobb-Douglas programming equates value of marginal products of inputs with prices of inputs, using supply and demand price schedules, without the necessity of the purchase and/or sales activities commonly used in linear programming. Regression-estimated Cobb-Douglas production functions have advantages in statistical tests of their accuracy. They also allow an infinite variety of input mixes to each productive process. In this study Cobb-Douglas programming is used to allocate land to crops prior to allocating other inputs to these activities. This sequential decision-making option is consistent with a study[3] which indicates that land allocation is the

[3] Glenn L. Johnson, et al., Managerial Processes of Midwestern Farmers (Ames, Iowa: The Iowa State University Press, 1961), p. 62.

first of a farmer's management decision which affect crop production.

In this study, the behavior of the Michigan agricultural sector is simulated for 1955 through 1962, although a run for a 15-year period was preferred. A 15-year simulation starting from 1955 would allow a comparison with finalized statistics on the actual production of the Michigan agricultural sector for the same time length as for projection runs. A 1955 through 1970 run was not executed because expected output prices are not endogenous to the model and these prices were available only through 1962.[4] Once an expected output price component and future national input and output price series are developed, the model can be used to make 15-year projections.

Organization of Thesis

The remainder of the thesis is organized into five major areas. First, an overview of the Michigan agricultural Sector (Chapter 2) briefly describes the characteristics of the sector and their implications for Michigan and this study. Chapter 3 reviews the studies which provide the intellectual basis for this study. Two comprehensive, noncomputerized, Michigan agricultural sector studies, Projects 80 and 80 & 5 are reviewed. Chapter 3 also describes development of the Michigan Agricultural Sector Study (MASS) project up to the beginning of this study. Since this study contributes to the model developed in a pilot study for the MASS project, particular emphasis is given to a description of that model. A description of the simulation of the production behavior of Michigan's agricultural sector developed in this

---

[4]Milbur L. Lerohl, "Expected Prices for U.S. Agricultural Commodities, 1917-62," Ph.D. dissertation, Michigan State University, 1965.

study is the third and next stage of the study. Two chapters are devoted to the model's description: Chapter 4 addresses the economic theory that is employed in the simulation modeling and Chapter 5 presents a mathematical description of the new production component and the changes required to insert the new component into the computer program of the pilot study model. The outputs from a selected set of model runs are compared for their ability to track using several methods of empirical analysis in Chapter 6. An evaluation of the data, parameters, and structure of the final model is also included along with implications about Michigan's agriculture and the MASS project in this chapter, to complete the fourth area of organization. Finally, a summary of the study and some of the major conclusions and implications drawn from it are discussed in Chapter 7.

CHAPTER 2

THE SETTING

The awareness that we live in a finite world with limited productive capabilities has created a growing concern about the future of food production and environmental quality. The United States space program has contributed significantly to an awareness of the limited size of earth and its resources. At the same time, it has provided great strides forward in the data processing and computational techniques. Machines used to coordinate safe passage to the moon and back also have the capability for providing memory and computational assistance in solving problems of our society.

Through division of labor, the world has created greater and greater specialization of the functions of individuals and geographical locations. Specialization creates increasing interdependence, communication complexities, and new and growing legal structures. Institutionalization of the functions of society increases the problems caused by perturbations in the system. The rapid communications of our day allow the immediate publicizing of problems. Thus, what were once insignificant problems or at least unperceived problems, have become perceived and resolution is demanded. Resolution of perceived problems in a system requires comprehension of that system.

One of the results of specialization in our world is the regionalization of productive capabilities. Iowa is known for its corn production, the Great Plains for the production of wheat, and Michigan for its automotive industry. Industrialization and urbanization have become so significant that serious questions have been raised about the future of agriculture in Michigan. The Governor's Special Commission on Land Use reported[1] in 1972 that agricultural land was an area of critical concern. The Michigan Department of Agriculture stated "it is of critical concern that conversions of agricultural crop lands stop immediately."[2] Arising from these concerns Governor Milliken in Executive Order 1973-2 established the Office of Land Use in the Michigan Department of Natural Resources, and the Michigan Legislature passed a bill (HB4244) to aid the preservation of farm land in Michigan. There exists considerable controversy about the seriousness of the situation and probably as many conceptualizations of it as there are concerned individuals. The purpose of this project is to take a step toward developing a precise and explicit conceptualization that will aid the understanding of Michigan's agriculture and provide assistance in guiding its future.

---

[1]Michigan Governor's Office, "Governor's Special Commission on Land Use Report," Lansing, Michigan, January 5, 1972, p. 16. (Mimeographed).

[2]Michigan Department of Agriculture, "Michigan Agricultural Land Requirements; A Projection to 2000 A.D.," Lansing, Michigan, February, 1973, p. 10.

The Importance of the Michigan Agricultural Sector

Agriculture is Michigan's second largest industry.[3] In 1974 cash receipts in Michigan from farm marketings totaled about $1.7 billion.[4] Combining production, transportation, processing, and marketing costs, agriculture contributed more than $3.5 billion to the state's economy. In 1974 the Department of Agriculture estimated that the average investment per worker on a Michigan farm was about $90,000, more than three times the amount invested per worker in the auto industry. Consequently, the 1972 real estate book value of Michigan's 81,000 farms totaled about 5.57 billion dollars. The estimated 1973 land value of the average 153-acre Michigan farm was $66,249, or $433 per acre.

These substantial investments are significant to the wealth and the welfare of Michigan. Agricultural productivity has increased twice as fast as manufacturing productivity in the past two decades. The average farmer of today produces 3.3 times more per man hour than did the farmer of 20 years ago. The result of great increases in agricultural productivity makes food costs in the United States a smaller percentage of the average worker's take-home pay than in most countries of the world. The high productivity in the national agricultural sector has enabled the United States to export large amount of farm commodities all over the world. Agricultural commodities are now the most significant category of exports in the national balance of trade.

---

[3]Unless otherwise noted, statistics quoted in this section come from Building Rural Michigan: A New Era in Agrarian Industrial Enterprise prepared by Gene W. Heck for the House Republican Caucus Rural Development Task Force, Republican Office, House of Representatives, State Capitol, Lansing, Michigan, January 1974.

[4]Michigan Crop Reporting Service, Michigan Agricultural Statistics, 1975, (Lansing, Michigan, June 1975).

A desire to maintain or increase the high rate of gain in agricultural productivity and output has engendered increasing concerns about the future of agriculture. Dominant among the concerns is the expressed desire to preserve our agricultural land for farm production. Other perplexing problems exist in the areas of transportation, environment, and energy use.

The dominant characteristic in the increase of productivity in agriculture has been the reduction of the labor intensiveness of the industry. Concomitant with this shift has been significantly increasing capital requirements per farm laborer. Most of this capital has been in the form of nonrenewable resources. This shift has caused some of the productive resources produced in the agricultural sector, labor being the most significant, to flow into the nonfarm sector, contributing significantly to the economic development of the nation.

Change is difficult for most individuals and the transfer of labor out of agriculture has not been painless. The desire of farmers to remain in agriculture has resulted in significant downward pressures on the return to labor in agriculture. A 1970 Michigan State University study[5] reveals that only 26 percent of all Michigan families live in rural areas, but 34 percent of all "poor" families are concentrated there. Accompanying the reorganization have been lagging farm income relative to nonfarm income, and governmentally owned stocks of agricultural commodities resulting from government attempts to improve farm product prices. In spite of lagging farm incomes, capital resource

---

[5]W. E. Vredevoogd, Rural Poverty in Michigan, Report No. 21 for the Center for Rural Manpower and Public Affairs, Michigan State University (East Lansing, November 1970), p. 2.

commitment to farm production continues despite low returns as compared to returns in the nonfarm economy.

Characteristics of the Farm Sector

Farm sector adjustment problems are most evident in low prices and/or surpluses of agricultural commodities. Certain characteristics of the farm sector and its environment combine to commit resources to the production of farm commodities, even when past experience indicates that resources so committed earn returns lower than similar resources committed to the nonfarm sector.

The farm sector is characterized by: (1) an inelastic demand for farm products, both with respect to price and income; (2) atomistic structure; (3) rapid technological change; (4) imperfect knowledge; (5) a family farm structure; and (6) large space and specialized input requirements.[6] To complete the list of circumstances which have combined to cause the adjustment problem in agriculture must be: (7) wars; (8) large fluctuations in the nonagricultural sectors of the economy; (9) unstable international demand; (10) government programs; and (11) variable weather.

Inelastic Demand for Farm Products

In the United States, the market price of farm products varies greatly with small changes in output. Brandow estimates the price elasticity of demand for all farm products at -.2278, and an income

---

[6]The discussion of these characteristics draws heavily from Dale E. Hathaway, Government and Agriculture (New York: Macmilland and Company, 1963); and also from Glenn L. Johnson, et al., Managerial Processes, p. 10 ff.

elasticity for all food of .26.[7] The low price and income elasticities of demand for farm products imply: (1) demand for farm products does not increase appreciably with higher incomes; (2) growth in demand is largely limited to population increases; (3) modest fluctuations in output lead to large fluctuations in commodity price; (4) total revenue declines with increases in output; thus it the growth in farm output exceeds the rate of population growth, there is a steep downward trend in commodity prices and resource earnings.

Atomistic Structure of the Agricultural Sector

The agricultural sector is an industry composed of small, relative to the total industry, widely dispersed firms, producing homogenous products. This characteristic is one means of defining pure competition. In the absence of coercion, strong producer bargaining organizations, or government action, the agricultural sector, with its atomistic structure, is unable to control aggregate output, prices, or the adoption of new technology in a manner that would ensure adequate returns to resources committed to agricultural production. Because there are so many firms in the agricultural sector, each making its own production decisions, accurate information gathering on actual production and production expectations is a very complex process. The size of the task makes it beyond the capabilities of most firms in the sector. Erroneous expectations of future market prices are costly to individual firms, and consistent errors in expectations across firms in the sector can cause major problems for the rest of the economy.

---

[7] G. E. Brandow, Interrelationships Among Demands for Farm Products and Implications for Control of Market Supply. Bulletin 680 (University Park: The Pennsylvania State University Agricultural Experiment Station, August, 1961), p. 17.

Underproduction can cause food shortages and overproduction implies an excessive drain on resources that receive a low return in light of the concomitant low prices.

In Michigan, both resources and income are taxed. Property taxes have an impact on the resources available to agriculture. Land availability is particularly affected by assessments based on potential land use instead of present use. Income taxes affect the ability of individuals in the agricultural and non-agricultural sectors to purchase productive resources. In addition to taxing policies, state spending, zoning and other regulatory policies affect the agricultural sector. Significant effort is made within Michigan to gather information on the production and welfare of the agricultural sector. The welfare of those in the agricultural sector and of the population of the state is enhanced by analysis of this information. Accurate projections of the future of the agricultural sector and its environment can be of use to farmers in making their production plans. It can also be of use to policy makers in their decisions which affect the agricultural sector, if projection methods are in a gaming mode which allows tests of alternative policies.

Micro-economic theory models usually divide inputs into two categories: variable and fixed. These models do not allow changes in resources normally considered fixed, although such changes do happen. Macro-economic models often lump all productive inputs into a single category called capital which is variable. But these models do not explain the lag between the increases in optimal agricultural farm size and their actual size.[8] This indicates that analysis desiring to reflect the behavior of the agricultural production sector must go beyond the traditional theory. In fact, inputs to the productive process are not bi-variate, that is, either totally fixed or totally variable. All factors of production have some characteristics of asset fixity and some ability to vary.

Resources employed in the farm sector become less responsive to changes in product prices when characteristics of the farm sector and its environment combine to cause wider divergencies between input acquisition costs and salvage values. In The Overproduction Trap,[9] recognition and consideration of the variable fixity of inputs contributed to an explanation of the present behavior and structure of the agricultural sector.

Rapid Technological Change

The trend in technical, economic, and institutional changes over the last half century in the United States has resulted, generally, in more and higher paying employment opportunities for labor in the nonfarm than in the farm sector and also has provided a rate of technological development and adoption in agriculture as fast or faster than

---

[8] Most farm firm production studies over the last two decades have consistently revealed constant or increasing returns to size, a condition which indicates nonoptimal use of resources if indeed they are as variable as macro-economic models indicate. See, for instance: J. Patrick Madden and Earl J. Partenheimer. "Evidence of Economies and Diseconomies of Farm Size," Size, Structure and Future of Farms. Edited by A. Gordon Ball and Earl O. Heady. Ames, Iowa: Iowa State University Press, 1972.

[9] Glenn L. Johnson and C. Leroy Quance, eds., The Overproduction Trap in U.S. Agriculture, (Baltimore: The Johns Hopkins University Press, 1972).

any other country in the world. The most significant advances in technology have been land- and labor-saving technologies. Many of the new inputs and technological advances in the use of traditional inputs have brought about significant increases in the economic size of farms, specialization on farms, and lower per unit costs.

Technological change has been a contributing factor to asset fixity. The adoption of new land- and labor-saving technology not only depresses the MVP's of land and labor but makes some existing capital inputs obsolete and, thus, decreases their MVP's. This means that much of this capital becomes economically fixed in the farm sector, often on specific farms, because of the great difference between salvage values and acquisition costs. The changes, also, have created very specialized inputs to the various agricultural enterprises. Specialization of inputs also increases asset fixity, since specialized inputs lack alternative uses. Asset fixity has been an important factor in maintaining the atomistic structure of agriculture but has also reduced the ability of the agricultural sector to adjust rapidly to changes in its economic environment.

Value of Projections of Agricultural Production

Rapidly rising food prices since 1970 and the resulting repercussions highlight the importance of comprehending the agricultural sector's response to its environment, so that more effective policies can be implemented. The decreasing amount of land available for agricultural production and the apparent misuse of land is a topic of ever increasing importance. The 1973 and 1974 shortages of inputs to the agricultural sector extracted costs that, even ex post are difficult to sort out. A valid forecast of input demand and the physical value of those inputs might have helped avoid shortages or at least helped establish a relative value of avoiding the shortages. Public information about agricultural production and input demand is important to agricultural producers, input suppliers, and urban dwellers. Such information should also be useful in formulating and evaluating policies and programs affecting the production (and marketing) of the major agricultural commodities.

Many individuals are involved in decisions and actions adjusting Michigan's agricultural sector to changing situations; many more individuals are affected by the decision made. The decision-makers include individual farmers, agricultural input suppliers, commodity marketing and processing agents, and individuals in state and local government. There is a need for these individuals to have a comprehension of the state's agriculture, alternative courses of action, and an understanding of impacts of those actions.

CHAPTER 3

ANTECEDENTS AND EVOLUTION

This study contributes to the Michigan Agricultural Experiment Station project 3169, titled Michigan Agricultural Sector Study (MASS). Two comprehensive Michigan agricultural sector studies[1] preceeded this project. Both drew from a wide variety of information sources with major inputs from Michigan State University staff members from the many disciplines represented in the College of Agriculture and Natural Resources. Since these two studies provided major inputs to this project, they and the MASS project are reviewed in this chapter.

Projects 80 and 80&5

In 1964, out of recognition of the need for greater knowledge about the present and future of the agricultural sector, the MSU College of Agriculture and Natural Resources, began a study titled Project 80--Rural Michigan Now and in 1980. Reactions to this project and the changes in rural Michigan by 1971 were significant enough to evoke an update (Project 80&5) to make projections of Michigan's rural potential through 1985. In both projects, the description of the causal relationships between the assumptions about the environment of

[1]Results of these two projects, Project 80 and Project 80&5 are published in Michigan Agricultural Experiment Station Research Reports 37-52 and 180-194, respectively.

rural Michigan and the projected sectoral behavior are insufficient for the derivation of a quantified model reflecting the impacts of changes in the economic environment on the behavior of the sector. Prices are spoken of only in very general terms. And the competition of various enterprises for inputs, including land, is not made explicit in the project. Each project wrote only one scenario of the future of Michigan's rural sector. No allowance was made for alterations of the basic assumptions; and, in most cases, knowledge of the relationships necessary to investigate such alternatives are not available. Within a year of the completion of Project 80 & 5, huge reductions in grain stocks in the United States and crop failures in significant regions of the world created repercussions which made many of the projections obsolete.

Starting in March of 1974, under the auspices of the Computer Library for Agricultural Systems Simulation,[2] information from the Project 80 & 5 reports was put on a computer in a format which permitted interaction with many of the parameters of the model to allow for model adjustment and experimentation among alternatives.[3]

Project 80--Rural Michigan Now and in 1980

In 1963, the Michigan Agricultural Conference requested that Dr. Noel P. Ralston, Director of Extension, make a study of Michigan's agricultural production and long-range potential, to include marketing

---

[2]The Computer Library for Agricultural Systems Simulation is a project of the Agricultural Sector Analysis and Simulation Projects at Michigan State University and funded by AID/csd-2975.

[3]This model is described in David L. Watt, "The Michigan Model," unpublished collection of papers for the Computer Library for Agricultural Sector Simulation, Michigan State University, May, 1974.

and related industrial and business activities.[4] The committee appointed to evaluate this request determined that such a study was worth undertaking and would need to be broadly based and interdisciplinary. A steering committee was appointed and Project 80 began.

The project perceived two major forces affecting Michigan's agriculture: external and internal. The first phase of the project looked primarily at the external forces on Michigan's agriculture. The goal of this phase was to establish realistic assumptions about technology, farm legislation, international trade, market structures, and population. Some of the assumptions made in this phase were: (1) no major war; (2) no major depression; (3) annual inflation of about 1.5 percent, (4) average weather and little success in controlling weather; (5) a more rapid development of new technology than in the previous 15 years; (6) a faster rate of adoption of new technology, and (7) the continuation of price support programs. Export programs, such as PL480, were expected to continue.[5]

Phase two of the project made projections of acreages, yields, crop production, livestock numbers, livestock production rates and total livestock production in Michigan. Factors considered in making these projections included the determination of what new technology would be adopted in production and marketing and what changes in life

---

[4]From the files of John Ferris, Department of Agricultural Economics, MSU. This request was in the form of a conference resolution. A copy of this resolution was attached to a letter dated October 11, 1963, from Ernest Girbach, President of the Michigan Agricultural Conference, addressed to Mr. Thomas K. Cowden, Dean of the College of Agriculture, Michigan State University.

[5]John N. Ferris, "Rural Michigan Now and in 1980: Highlights and Summary," Michigan Agricultural Experiment Station Research Report 37, (East Lansing, Michigan, 1966), pp. 5-6.

styles of participants in the agricultural sector would occur. Committee organization during Phase two centered around agricultural commodities. Tests for internal consistency between commodity projections for the total project were carried out by the steering committee and meetings of representatives from the various committees.

Phase three looked at adjustments in resource use and marketing channels. This phase looked specifically at intra-production firm adjustments, intra-marketing firm adjustments, nonfarm employment opportunities, and aggregate projections of Michigan gross farm income, net farm and nonfarm income, number of farmers and gross investment.

The first three phases of the project resulted in the preparation of some 50 discussion papers. Many rural leaders and representatives of businesses directly concerned with the rural economy participated in the project by reviewing these papers, offering suggestions, and submitting ideas for needed programs. About 200 of these individuals joined 100 campus-based faculty members in a two-day seminar during spring 1965 to review the papers. Several other meetings were held for this purpose, including a two-day workshop for the entire faculty of the College of Agriculture and members of the Extension Service field staff.

The staff involved in the study responded to many requests throughout the state to present and discuss Project 80 results. Indications are that the results were found to be of value to a wide group of people within the state--farmers, agribusiness firms, farm organizations, legislators. "Through broad involvement of individuals both within and outside the College (of Agriculture) and through wide publicity, Project 80 caused things to happen. Its influence was felt not only in the programs of the College but also in the programs and activities of other organizations and individuals in the rural scene."[6] Success of the project and the dramatic changes in rural Michigan led to a reassessment of the projections in Project 80&5.

Project 80&5--A Look at Michigan's Rural Potential in 1985

The steering committee for Project 80 met to discuss an updating of the project in April of 1971. A look at the developments in the five years since Project 80 resulted in their deciding to repeat the project using the same basic structure and projecting to 1985.[7] A Delphi survey was also conducted to solicit faculty judgments on "what major new developments will shape rural Michigan between now and the year 2000?" In the study, Phase one looked at the forces which influence rural Michigan but over which rural Michigan has little or no control. This was similar to Phase one of Project 80. Phase two dealt more intensively with rural Michigan itself, its commodities, services and people. And Phase three directed itself toward the question of what should be done to shape the future.

The study began with a look at the United States Gross National Product and price levels and projected these to 1985. This was followed with a look at national, state and local tax systems and a qualitative look at the environment and quality of life. Then, moving on

[6]Michigan Agricultural Experiment Station, "Highlights and Summary of Project 80&5," Research Report 180, (East Lansing, Michigan, 1973), inside front cover.

[7]Memorandum from John Ferris to Steering Committee, Project 80&5. Informal minutes of the Steering Committee meeting of April 16, 1971, dated May 17, 1971.

toward the area of more specificity, was a look at food consumption in the United States looking specifically at trends in consumer demands, nutritional factors and per capita consumption, present and projected. Specifically, within the agricultural sector, U.S. agricultural trade, food systems marketing structure, food processing technology, emerging directions in U.S. agricultural policy, agricultural labor technology and research, weather, information systems, and the adopting of agricultural technology were studied and projected. Within the State of Michigan, trends in land and water use and the demand for recreation resources were considered as major factors influencing the agricultural sector. These studies set the environment for the study of the Michigran agricultural sector. Specifically, the study of the agricultural sector was divided into three major areas:

1. agricultural commodities,
2. natural resources, and
3. rural people and rural living.

The latter two categories used the conclusions of Phase One as major guidelines for making their projections. Those involved in making projections for specific commodities within the State's agricultural sector were furnished with data on acreages, yields, production, livestock numbers, livestock production rates, and total livestock production in Michigan and in competing areas for the period 1920-1971. Michigan production as a percentage of total U.S. production was calculated for these years and a regression line was derived from the percentages. The regression line was extended to the year 1985 to establish an initial estimate of Michigan's percentage of the total in 1985. In addition, the average percentages of Michigan's production in

1969-1971 were calculated as a base for projections. Each commodity committee was then asked to estimate what new production and marketing technologies will be developed in the next 15 years and to what extent the new technologies would be used and what their impacts on yield, production, feed requirements, capital and labor inputs, and other production coefficients would be. They were directed to give particular attention to any differences in the impact of technology on Michigan relative to other parts of the country. The committees were directed to go into detailed narrative in describing new technologies and their impacts on resource allocation.

The information and directives to the commodity committees resulted in a great deal of consistency on types of information provided for each commodity, but differing disciplinary backgrounds, interests and knowledge resulted in not as much consistency as the steering committee desired.[8] The commodity-based structure of the study also resulted in a lack of description of the causal factors involved in competition for resources between commodities within the state. Many of the inconsistencies coming from the committee reports were resolved through action of the steering committee and project seminars. The logic of compromises made in this process, however, were not documented to the degree necessary for these kinds of adjustments to be included in a formalized model of the sector.

The methodology used in Project 80&5 requires a complete repeat of the total process in order to update the project results when its basic assumptions are violated to an extent sufficient to invalidate its projections. A more efficient method of analyzing the consequences

---

[8] John Ferris, personal communication, October 1975.

of changes in the economic environment of Michigan's agriculture, such as government policies and changes within the Michigan agricultural sector, would be of significant value. Recent developments in the data processing technology permit an alternative methodology for making projections with similar validity, greater flexibility, and lower cost. The computerization of Project 80&5 results was a step in this direction.

During the early stages of Project 80&5, the development of a simulation study of the Michigan rural economy was discussed.[9] This simulation study was suggested to run concurrently with Project 80&5 to complement and reinforce the more informally structured project. A concurrent simulation project did not take place, but a computerized simulation model described in the following sections, was developed based upon the results of Project 80&5.

The Michigan Agricultural Sector Study

The Michigan Agricultural Sector Study (MASS) is a project of the Michigan Agricultural Experiment Station. Conceptualization of the project began almost two years before its approval in June 1975.

The technology of computer-based simulation modeling is advancing rapidly. Computer hardware is undergoing rapid advance with the concomitant decreases in cost. Software development is extensive and popular. The ground-breaking research methodology used by Jay Forrester in World Dynamics and later used by Meadows, et al. in "The Limits to Growth" model are prime examples. The Nigerian and Korean computer-based

[9]Memorandum from John Ferris to Steering Committee, Project 80&5. Informal Minutes of the Steering Committee Meeting of April 16, 1971, dated May 17, 1971.

modeling efforts at MSU have brought subject matter knowledge into use in the computer-based technology of projection. Now appears to be an important time to influence developments in a manner that will enhance their use in computerized studies of agricultural sectors. While the Forrester and Meadows models were based on the electrical engineering fostered structures used in systems science, the Nigerian and Korean studies emphasized the use of the computer as a computational tool synthesizing multidisciplinary inputs to the study with quantification being the main constraint on the entry of information into the computer program.

Projects 80 and 80&5 provide an information base which is quite adaptable to a computerized agricultural sector model since both projects emphasized quantification. A review of the six studies mentioned in the preceeding paragraph and a regional model of the Susquehanna River Basin by Batelle Institute, indicated that a Michigan agricultural sector model could serve as a focal point for assembling and organizing information which would aid agricultural decision making. The Michigan Agricultural Sector Study (MASS) is a project of the Michigan Agricultural Experiment Station.

> The objective of this research project is to develop a comprehensive model of the Michigan agricultural sector which will:
> 1. improve the decision making capabilities with respect to long-range planning in Michigan agriculture and related activities.
> 2. provide a means for integrating previous research, expert judgment and new quantitative analysis into a composite projection model.

3. improve the methodology in simulating and projecting in agricultural sectors for analytical and planning purposes.[10]

The conceptualization of a Project 80&5 based computer model began in November 1973 as an attempt to address the perceived problem in Michigan of rapidly decreasing agricultural lands. The specific objective of the study was to be a look at alternative state land use policies and their impacts, with particular emphasis on the then proposed Green Belt Act.[11] The expected result of this study was a prescription for legislative action.

An investigation providing prescriptive conclusions of what should be legislated require a multidisciplinary approach, but tend to be complementary to disciplinary research. These prescriptions result from an impact analysis of various alternatives. It would need to ask, "What feasible future policies will yield desirable or at least acceptable impact?"

A feasibility evaluation using the systems approach[12] indicated the number of causal relationships requiring quantification to reflect the differential impacts of alternative legislative proposals was too large to accomplish without significant increases in available information about the agricultural sector.

---

[10]Michigan Agricultural Experiment Station, "Michigan Agricultural Sector Study (MASS)," Project 3169, February 1975.

[11]The "farmland and open space preservation act" (HB4244) was approved by the Governor May 23, 1974 as Act No. 116 Public Acts of 1974.

[12]The evaluation used in the procedure described in: Thomas J. Manetsch and Gerald L. Park, Systems Analysis and Simulation with Applications to Economic and Social Systems Part I, (East Lansing, Michigan: Department of Electrical Engineering and Systems Science, 1974) Chapter 2.

This conclusion resulted after analysis of input from many researchers with experience in land use and systems science. These researchers included crop and soil scientists, systems scientists, Dr. Daniel Chappelle of Resource Development at MSU and Dr. Jim Ahl from the Michigan Department of Natural Resources plus several members of the faculty of the Department of Agricultural Economics at MSU. The soil scientists indicated there was no consistent survey of soil types or soil capabilities presently available. However, a current project will provide such information upon its scheduled completion in 1977. Jim Ahl said that his office was surveying present land use in Michigan but the completion date of that survey was dependent on future funding. Thus, a significant shortage of data exists at the present time and a land use alternative modeling effort would be much more feasible at a later date. Indications are that the data, parameters and model structure of a rough study based on presently available data would soon be obsolete. The feasibility study did reveal that sufficient data existed for a general agricultural sector model which would provide a basic framework for the development of a model capable of evaluating legislative alternatives.

The Michigan Model

In March 1974, the Computer Library for Agricultural System Simulation[13] was preparing for the May meeting of its Policy Advisory Board. One of the objectives for the May meeting was to demonstrate the capabilities of the computer library by developing an agricultural

---

[13]The Computer Library for Agricultural Systems Simulation is a Project of the Agricultural Sector Analysis and Simulation Projects at Michigan State University and funded by AID/csd-2975.

sector model that had not been used in the development of computer library components. A feasibility study indicated a demonstration model of Michigan's agricultural sector would be worthwile. The model developed in this effort served as a pilot study for the MASS project and provides the basic model this study seeks to improve.

For the demonstration, the Computer Library staff wanted a simulation model that was both simplistic and comprehensive enough to include the total agricultural sector. Simplicity was desired to make the simulation easily understood, compatible with present software components, and low in developmental and operational costs. Comprehensiveness permits observation of the direct and indirect policy impacts. At the same time, a simplistic model minimizes the complexity of policy changes and their impacts. These requirements were established to maximize both the hands-on feel of the simulation model and an appreciation of the software components during a demonstration.

A computerized simulation is developed in two steps; first, abstractions from the system being modeled are made to develop a mathematical model; then the mathematical model is programmed into a form that can be processed by the computer.[14] The following discussion is divided into two sections to make this division explicit.

The Mathematical Model

The demonstration model centered on the level of self-sufficiency in 16 different crop and livestock activities presently in production in the state. Project 80&5 estimated and projected human consumption and

---

[14]Thomas J. Manetsch and Gerald L. Park, System Analysis and Simulation with Applications to Economic and Social Systems, Part II, (East Lansing, Michigan: Department of Electrical Engineering and System Science, 1974), Chapter 8, p. 1.

production of agricultural products in the state. Although no self-sufficiency ratios were developed in these projects, the simulation model calculates them using the accounting component of the software library. Seven (7) components of the software library are used: two demographic components, two table components, two delay components, and an accounting model. Figure 1 displays the major subsectors, flows and output of the economic conceptual model, and will be explained starting with the population and migration model and progressing along the product flow arrows.

The population and migration component starts with the 1970 population of Michigan broken into two groups: farm population and non-farm population. Migration to and from the state is assumed constant in absolute numbers, and equal to the average age-sex specific migration between 1960 and 1970. Rural-urban age-specific migration rate (as a proportion of farm population) is assumed equal to the 1960-1970 Michigran rate. Age-sex specific mortality rates are considered to be constant and equal to the 1970 rate. Fertility rates include the actual 1970 age-specific fertility rates, the actual 1971 age-specific fertility rates, and are assumed to proportionately decrease from the 1971 rate to values consistent with zero population growth (ZPG) by 1960.

The land allocation component separates land into two categories: non-agricultural demand for land and agricultural land. Total land in the state of Michigan is 36,492,000 acres. The nonagricultural demand for land is assumed to be 3.00 acres per person in the nonfarm population and 2.75 acres per person in the farm population. Conceptually, this demand for land is demand for urban residences, forests and

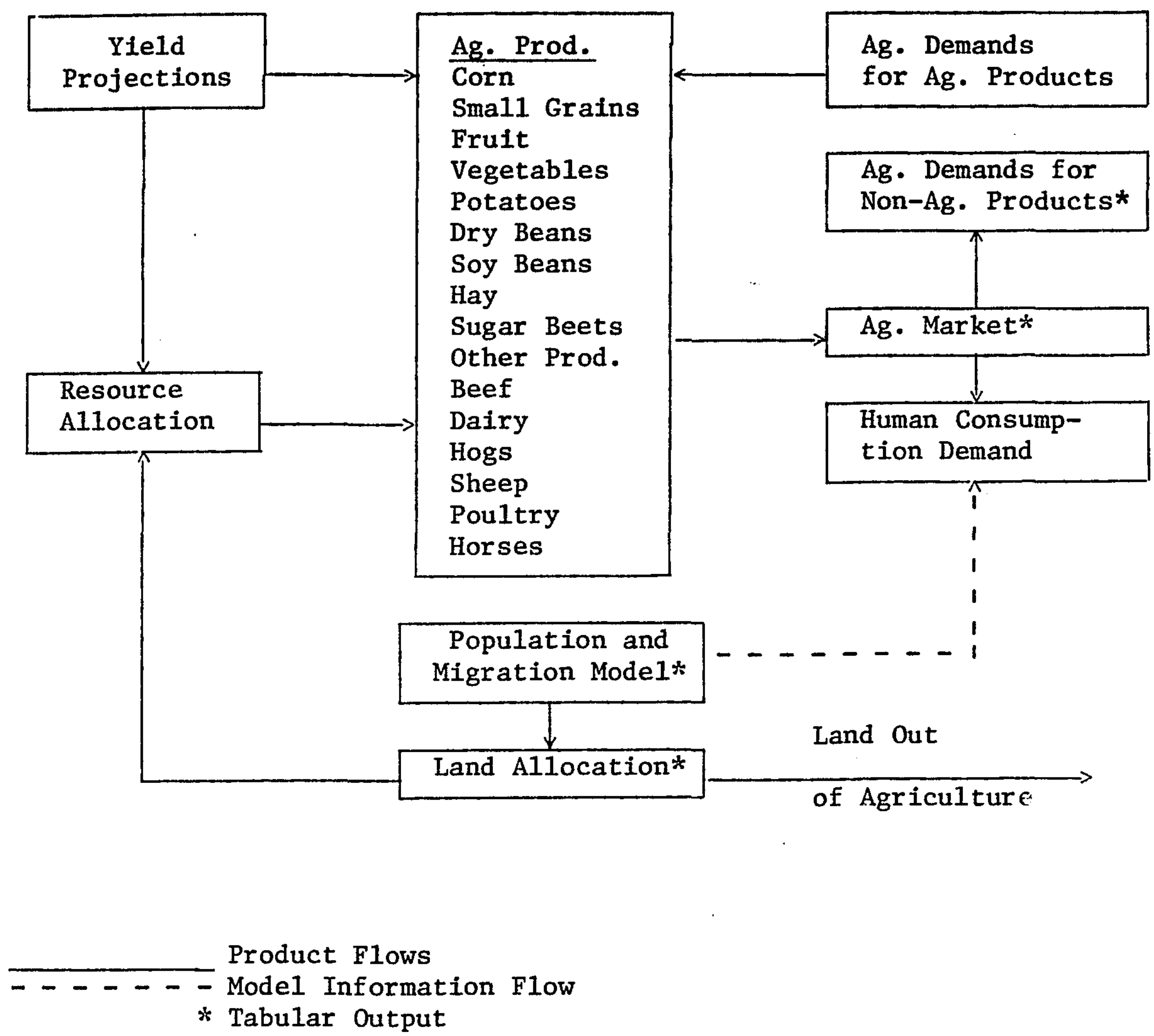

Figure 1: Major subsectors, flows and output of the economic conceptual model.

recreational lands, public forests, parks and recreation area, wildlife areas, private forests and recreation land, highways and roads, other transportation areas, national defense areas, industrial and service areas, and miscellaneous and idle nonagricultural demands for land. Nonagricultural demand for land is substracted from total land to derive agricultural land, reflecting the higher price of nonagricultural land.

The resource allocation component estimates livestock numbers and proportion of agricultural land in each crop category. Crop and livestock categories are listed in the agricultural production component block in Figure 1. Excepting dairy, the number of all livestock are a linear interpolation between the 1969-1971 average and the 1985 projection drawn directly from Project 80&5. The dairy cow population is modeled using a demographic component from the software library, the 1970 population of dairy cows and estimated fertility, mortality, and cull rates (culls from dairy herds include the exit of dairy herds from Michigan through sales either to the slaughter industry or to other states' dairy herds). These rates force the model projections to coincide with the dairy specialists' projection for 1985.

The yield projections component serves two functions for the overall model: First, to determine total production given the acreage allotments to each agricultural product and second, to allocate resources. The quantities from yield projections are not used directly in programming methodology within the resource allocation component but are taken into consideration by those designing the resource allocation component parameters. The yield projection component consists of a group of equations where yield is a function of time.

The agricultural production component consists of a series of equations indicating the demand for both agricultural and nonagricultural inputs as a function of the allocation of land to each particular crop and the number of livestock raised. For instance, one dairy cow requires X1 quantity of corn, X2 quantity of wheat, X3 quantity of labor, X4 quantity of capital resources, etc. Yield projections are multiplied by resource allocation to determine agricultural production going to the agricultural market.

The agricultural market component calculates the net flows of each agricultural product in or out of the state by substracting agricultural demand and human consumption demand from agricultural production. The agricultural demand for agricultural products is the sum of input demands for agricultural products from the production component; and the agricultural demand for nonagriculturally produced inputs is the sum of all nonagriculturally produced inputs. The human consumption demand for agricultural products is calculated by multiplying the Michigan population by the linear interpolation of 1970 actual per capita consumption levels and Project 80&5's projected 1985 per capita food consumption and demand for horse services. Agricultural production is not constrained to be equal to agricultural demands for agricultural products plus human consumption demand because the residual, either positive or negative, is the net flow in or out of the state for that product.

Formal System Model

One of the major reasons for translating a conceptualized mathematical model into a formal systems model is to determine particular time solutions when nonlinearity, randomness, or sheer complexity preclude normal analytical techniques.

The model is almost too simple to be considered a system because there is little interaction between components and no feedback loops or nonlinearities. The formal system model derived (Figure 2) consists of six components. The human population component is basically the same as described in the economic conceptual model. The livestock population component and the land allocation component make up the resource allocation component in the economic conceptual model; they were separated because of their basic computational differences. The production component in the formal system includes both the yield projections and the input-output table of the agricultural production component in the economic conceptual model. Due to similarity of utilization and derivation of demand and supply quantities, the agricultural demands for agricultural products, agricultural demands for nonagricultural products, and the human consumption demand components are are combined in the system model into the demand component. It computes the inputs demanded for agricultural production, human consumption demand for each agricultural product, and the difference between supply and demand (the net import-export quantity for each product). The accounting component in the formal system model comes directly from the software library. Calculations made in this component include: expenditures on inputs, gross income, farm consumption, cash income, total profits, net profit, value added, taxes, and per unit profits both net and total.

The development of the Michigan Model would have been a very difficult task without the experience gained from the MSU projects which simulated the Nigerian and Korean agricultural sectors and the Computer

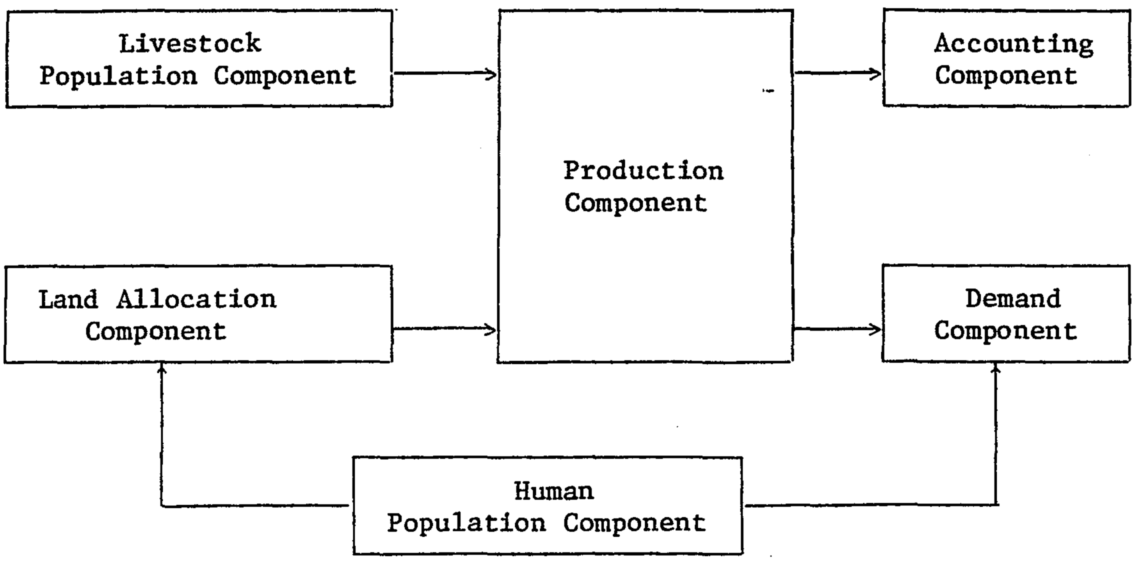

Figure 2: Data Information Flows in Simulation Model

Library components derived from these projects. The model developed was very close to the size and complexity of the Korean model developed at the end of the first year. The major difference between the two models was that the Korean model had several policy alternatives built into it while the Michigan Model had only a basic set of assumptions to follow. However, the design of the Michigan Model with its conversation capabilities created a much more usable and flexible model than was developed in the first phase of the Korean effort.

Modular Construction

The Michigan Model was developed with what can be considered a modular approach. Through the use of an executive program each component of the model is called as it is needed. The separation into component parts allows the separate parts to be evaluated and expanded and the level of aggregative detail within components to be changed without disturbing the remainder of the model in a major way. Through the use of various levels of detail within the components, a user can adjust the model to deal with the specific problem being researched without the model being so large and complex that it requires an inordinate amount of computer time.

Analytical Needs Governing Further Research

There are significant research needs for policy analysis of alternatives open to Michigan decision makers. These alternatives include the areas of land use legislation, labor laws, real estate tax, energy availability, and environmental laws. Many future scenarios for Michigan include impacts of events from outside Michigan. These events could create serious changes in Michigan's agricultural comparative advantage, either in total or in specific crops. There is a need to have the analytical capabilities to study impacts of changes in relative prices of goods and services related to Michigan agriculture. Federal laws on land use, pollution, private and corporate income tax, labor, energy, and specific agricultural legislation, such as commodity programs and marketing orders are also important topics of analysis. Michigan is a significant contributor to U.S. export of dry beans, along with some other agricultural commodities. Analytical capabilities of the impact of changes in world export/import patterns would be beneficial for the establishment of priorities within the state. The changing of transportation costs through changes in transportation systems and marketing laws are also important.

Project 80&5 results, even when computerized with interactive capabilities, still have severe limitations due to lack of causal relationships between many variables which are closely linked and lack of important feedback loops.

The purpose of the MASS project is to provide a better analytical tool for researchers projecting the behavior of Michigan's agricultural sector for policy analysis, impact analysis, and decision rule sensitivity, in a mode that is well documented and lends itself to communication to decision makers. Specifically, the focus of this contribution to the MASS Project is to develop an improved production component for the Michigan Model which will reflect the production behavior of agriculture under a variety of economic conditions.

The component should be usable directly in analysis for the Michigan agricultural sector and adaptable to use for similar agricultural sectors. For example, one might be interested in examining the production behavior of the agricultural sector in response to a policy which directly, perhaps through taxation, or indirectly increases the cost of an input to the sector. The sector model should be capable of reflecting the impact on the inputs and outputs of the sector. It is also desirable that the component be grounded in economic theory to a degree which would allow generalization or adaption to use with agricultural sectors of other regions. There is dual reasoning to this desire: first, computer programming allows the transfer of research methodologies from one research project to another; and second, there is a reduction in cost of doing regional sector studies if generally applicable assumptions are used in the modeling process.

Clarification of Descriptive Terms

The definition of several terms and concepts will aid the reader's comprehension of the remaining chapters. The Michigan Model refers to the model described in this chapter. The purpose of this study is the improvement of that model through the development of a better production component. The model with its new production component and concomitant changes is called the Michigan Agricultural Sector Study model or MASS model. The term model when used as a noun refers to an abstract or simplified representation of some object, process or system. In this study it refers to a computer program representing the agricultural sector. Unless context indicates otherwise, it refers specifically to the model which resulted from this study. When used in a verb form, it refers to the process of developing a model, to include the development of its component parts. Both the Michigan Model and the MASS model are a combination of submodels, called components. Components are interrelated by linkages of common variables which are passed between components. Variables passed from one component to another are called outputs of the first component and inputs of the second component. Component outputs and inputs can be, but are not necessarily model outputs. Since the model is a combination of components any model output is also an output of some component.

CHAPTER 4

THEORY AND LOGIC OF THE MODEL

The primary objective of this study is to develop a production component for the Michigan Agricultural Sector Study (MASS) which reflects the economic and physical relationships relevant to the determination of quantities of commodities produced and inputs used. Insertion of this component necessitated several changes in the model structure. Although the modified model, labeled MASS model for expository purposes, retained the production component (PRODCN) to provide expectation estimates for commodity marketing channels and input suppliers, three new components were added. These three were: a production component (CDPROD) using Cobb-Douglas production functions, an input supply (INSUP) component and output demand (OUTDEM) component. The purpose of these latter two components was to provide price-quantity schedules defining the economic environment of the production decision makers. This chapter presents the economic theory employed in the development of the new components and the logic of the additional changes made to the model.

Selection of Time to be Modeled

Project 80&5 selected a 15-year time horizon as the length of time of most significance to planners. Uncertainty of future events and developments, especially in technology, make accurate projections past a 15-year period very difficult when using an iterative or recursive model. This is especially true when projections errors have a tendency to be aggregative over time.

A major consideration in the selection of time period for this study was the impact and contribution to the overall development of the Michigan Agricultural Sector Study. The combination of: (1) the desirability of having a 15-year validation run, (2) the availability of initialization data from the 1954 Agricultural Census and, (3) the designation of 1955 as the beginning of an era of growth and general expansion in U.S. agriculture[1] led to the decision that the use of the 1955-1970 period for validation and the 1970 to 1985 period for projection would be desirable for the MASS Project.

Unfortunately, much information about the U.S. agricultural sector essential to the model developed in this study is available only for the years prior to 1963.[2] Therefore, the model is restricted to the 1955 through 1962 time period for this study. The 1955 to 1962 time period was used in the expectation that after better weather, expected commodity price, and actual commodity price components are constructed, the 1955 to 1970 time period can be used for model validation runs. At that point projections to 1985 can be made with a model starting from 1970.

---

[1]Leroy C. Quance, "Farm Capital: Use, MVPs, Capital Gains or Losses," (unpublished Ph.D. dissertation, MSU, 1967).

[2]The expected and actual commodity prices from Milburn L. Lerlohl, "Expected Prices for U.S. Agricultural Commodities, 1971-62," (unpublished Ph.D. dissertation, MSU, 1965), and the updating of the Stallings weather index in Kost, William E., "Weather Indexes: 1950-1963," Quarterly Bulletin, Vol. 47, No. 1, (East Lansing: Michigan Agricultural Experiment Station, 1964), pp. 38-42, provide information that could only be developed in this study by a large additional research and modeling effort.

General Theory of the Production Component

The production component constructed in this study is an aggregate sector level model. The production behavior is simulated over the selected time horizon (1955 through 1962) to determine the feasibility of this type of modeling, to discover areas of further research crucial to the accuracy of the modeling effort, and to provide a basis for further development of a useful tool for policy analysis. Thus, both the physical structure and the behavioral theory employed are of primary importance in the construction of the simulation.

For the purpose of this study, "Simulation is defined as a numerical method to describe the behavior of a system under a finite number of randomly or independently selected environmental conditions."[3] Structural simulation was chosen for this study. Structural simulation is defined as simulation which concentrates on the physical interrelationships within the system being modeled. The popular alternative to this form is econometric simulation, using least squares estimated equations often of reduced form. Structural simulation was chosen to make explicit the physical flow of goods and services within the component and to allow further refinement of the model through enterprise or input allocation modeling. In its present format a more refined simulation of, for example, dairy or land allocation, can be built and used without requiring significant changes to the production component developed in this study. The more refined modeling can precede the production component with its results being fed into the production component

---

[3]Hartwig deHaen, "Systems Models to Simulate Structural Change in Agriculture," European Review of Agricultural Economics, Vol. 1, No. 4 (The Hague, Netherlands: Moulton, 1973), p. 367.

or follow the production component with the results overriding production component output.

Component Identification

The system to be modeled is the production of agricultural commodities in Michigan. The first step in any modeling endeavor is to identify the boundaries of the system being modeled. This is accomplished by identifying the important inputs determining the behavior of the system and the outputs which define the behavior or performance of the system. In this case, the system to be modeled is a part of a larger model. This system can be conceptualized as a black box which performs its functions in response to its environment (see Figure 3). The primary performance variables of the production component needed by the larger model are the quantities of agricultural commodities. Additional performance variables are identified in this discussion, but lack of data eliminates their use in empirical validation of the final component. The system inputs required from the larger model or exogenous sources are demand schedules for Michigan commodities, supply schedules for the factors of production used by agriculture, government programs or policies, level of technology used in agricultural production and weather.

The supply schedule for all inputs available to the agricultural sector and the demand schedules for commodities produced by the agricultural sector are exogenous to the component, in the present model, but the behavior of the component in previous time periods has an important impact. For example, the hours of tractor use in one year affect the price-quantity relationships in the following year, and the amount of corn moving through marketing channels in previous years

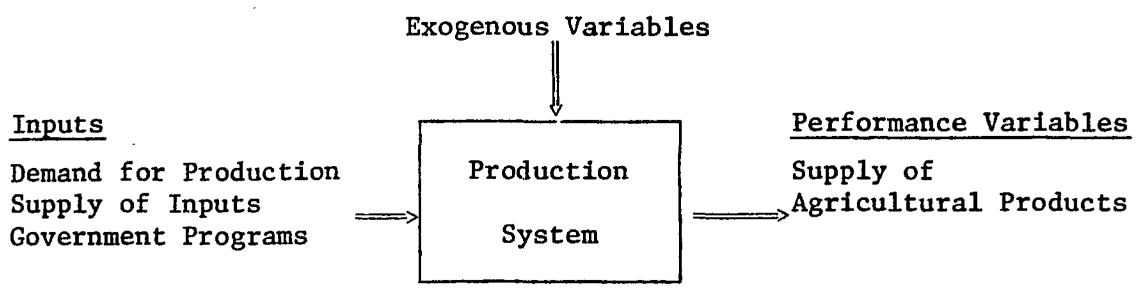

Figure 3. System to Reflect Productive Process

affects the capacity of marketing channels, this capacity has an impact on the farm gate price of corn. Price of corn is assumed to be negatively correlated with quantity of corn production. The technology level in the production process is exogenous to the component. Weather, an uncontrolled input in the production process, is also an exogenous factor.

The commodities included in the component are the ten which had the highest cash receipts in Michigan for 1971 as listed in "Farm Income and State Estimates, 1949-73," plus hay, horses and a category called other. Hay was included because it is much more important than its fourteenth rank in cash receipts implies, since much hay is used on the same farm that produces it and since more land is in hay than in any other single agricultural crop in Michigan. Horses were included because their numbers have increased rapidly in Michigan until they have become an important production item and Project 80&5 slates them for further gains. The "other" category was included to reflect the competition for agricultural inputs between other sector activities and the 12 specific commodities included. Table 1 lists the ten commodities having the highest cash receipts and hay (the fourteenth highest) with their respective value and percent of total cash receipts for 1971. Cash receipts for horses in Michigan are not included in the source referenced.

The inputs included in the component are crop land, labor and capital. Capital is subdivided into 22 categories. These capital inputs are labeled: (1) fertilizer, (2) dairy cows, (3) durable capital, (4) expendable capital, (5) corn, (6) hay, (7) protein feeds, (8) tractors with attachments, (9) combines and pickers and (10-22) one

Table 1

Cash Receipts by Commodities for Selected

Commodities, Michigan, 1971

Commodity	Value in 1000 dollars	Percent of Total
Milk Wholesale and Retail	277,725	28.5
Cattle Calves Meat	130,443	13.3
Corn	75,523	7.7
Dry Beans	66,575	6.8
Hogs--Meat	55,055	5.7
Soybeans	38,098	3.9
Eggs	34,479	3.6
Wheat	22,816	2.3
Potatoes	21,287	2.2
Sugar Beets	18,961	2.0
Hay	11,601	1.2
	TOTAL	77.2

Source: U.S. Department of Agriculture, Farm Income State Estimates 1949-73 FIS 224 Supplement, Sept. 1974. pp. 63-64.

category called enterprise fixed capital for each of the 13 commodities. The two major criteria for selecting these categories were value as model outputs and input characteristics. Input characteristics considered were the commodities in which each input is used and the degree of asset fixity as reflected in the differentiation between acquisition and salvage prices. The acreage impact of governmental programs in corn and wheat are exogenously included in the component.

Causal Relationships Within the Component

The causal relationships modeled can be broken down into two general areas--physical relationships and behavioral relationships. The physical relationships are between the quantity and mix of inputs and the quantity of outputs produced. An increase in the quantity of an input causes an increase in the output of the productive process in which the increase is used. The underlying behavioral theory used is, generally, a static neoclassical theory of the firm with asset fixity modifications. The state agricultural sector is assumed to behave as a profit maximizer subject to the constraints imposed by price structure, institutions, risk, uncertainty, and decision maker's perceptions and preferences. The basis for sector level decisions affecting the level of production activity and kinds of quantities of inputs utilized can be broken down into three general areas: (1) perceived prices, both expected prices for output and actual prices of inputs, (2) the input-output relationships expected by decision makers in the sector: and (3) the decision-making mechanism used to determine input quantities.

Price Considerations

If the aggregate farm sector is viewed under the classical assumption that each input is either variable or fixed, (i.e., for all variable inputs acquisition costs equal salvage values; while, for all fixed factors acquisition costs are infinite while salvage values are zero) there is some optimal allocation of resources represented by a high profit point on a factor-factor graph. In this classical model perfect adjustments in the use of variable inputs to the equilibrium high profit point occur by equating the marginal value products with the price of the variable inputs. But, this theory does not explain the adjustments observed in the farm sector in the factors considered fixed.

An extension of neoclassical theory advanced by Glenn Johnson contains more explanatory power than the unextended neoclassical theory. Legal, transportation, storage, advertising and other transaction costs, including changes in interest rates, cause input acquisition and salvage prices to diverge not only between different time periods but within the same time period. In recognizing that normally, and especially with durable resources, acquisition prices exceed salvage prices, Johnson defines a fixed asset as one that "is not worth varying."[4] That is, an input is economically fixed if its value in use or marginal value product is less than its acquisition cost but greater than its salvage value. In this situation there is no high profit point but an area toward which adjustments are made. The degree of success to which adjustments toward this area are made depends upon the starting point

---

[4]Johnson, Glenn L. and C. Leroy Quance, The Overproduction Trap in U.S. Agriculture, (Baltimore, Maryland: The Johns Hopkins Press, 1972).

in terms of input quantities and the physical and price perceptions of the decision maker in the production process.[5] In this study the concept of divergent salvage and acquisition costs for all inputs is used. But, since sector level modeling involves an aggregation of many decision makers, each of whom begins with different input mixes each year and different perceptions of the price relationships, some adjustments in input use are expected in response to a change in the expected price of output. This is reflected in the price-quantity schedules used in the model by making them continuous and monotonic (having a slope of the same sign throughout their relevant range). The price-quantity schedule for each input is specified by four points on a two-dimensional graph. (Figure 4) The requirement that each schedule to monotonic and the assumption that there is a positive relationship between price and quantity results in the constraints that; $Q_1 < Q_2 < Q_3 < Q_4$ and $P_1 < P_2 < P_3 < P_4$. Detail about the quantification of these points is included in Chapter 5. Major consideration in the determination of these price-quantity schedules is the degree to which institutions, history, and nature of the input affect its shape. For most schedules of inputs that are considered more fixed, usually due to durability, the difference between P_2 and P_3 is the hypothesized to reflect the influence of the difference between salvage and acquisition prices. In schedules for variable inputs with one time use that are usually procured from outside the Michigan agricultural sector (inputs like fertilizer, expendable capital, and high protein feeds) the point (P_2, Q_2) is the point where a significant increase in transaction, transportation, and

[5] C. Leroy Quance, "Farm Capital: Use, MVPs, Capital Gains or Losses," (unpublished Ph.D. dissertation, MSU, 1967), pp. 21-27.

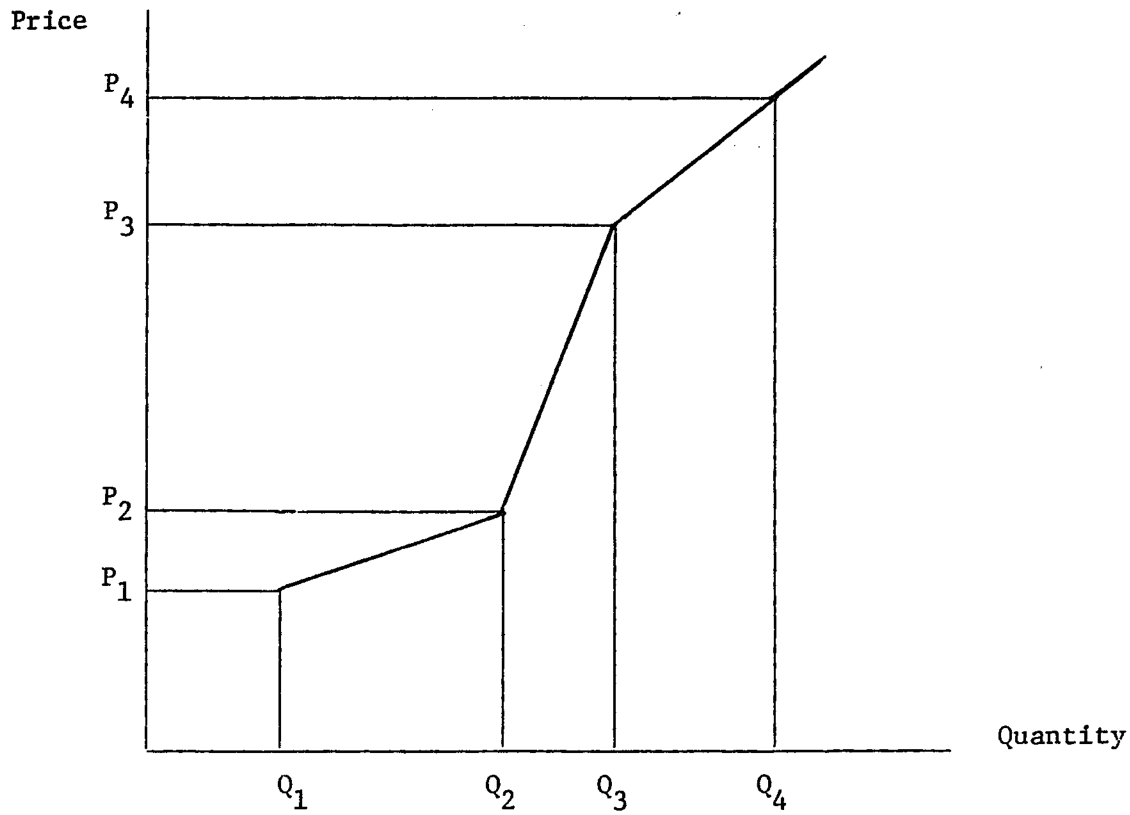

Figure 4: Example of a price-quantity schedule for an input to the production process.

organization costs occurs with increased input use. The determination of price-quantity schedules for both inputs and outputs was an ad hoc iterative process. It began by asking "What is the general shape of the schedule?" Estimates of elasticities were made by attempting to look at farmers perceptions of prices, that is the costs through application of the input into the production process and the value of output at the end of the productive process, over wide quantity ranges. These estimates were used in the component and the behavior of the system was checked for consistency. Where sources of inconsistencies were traceable to the price-quantity schedules, they were adjusted. This admittedly ad hoc methodology, while not optimal was necessitated by the great lack of information about aggregation of price relationships in the estimation of decision making at the sector level.

Analytical Methodology

The purpose of the MASS Project is to provide a tool to estimate impacts on the agricultural sector of Michigan created by exogenous factors which affect the environment of the sector. Both immediate and long-range impacts are of interest. Since many of the productive processes in the sector are annual, a model which reflects yearly activities is needed. While within year information is desirable, the additional modeling effort required is not feasible at the present. The component solves for annual levels of input and output quantities.

The broad information requirements of the model uses information from many disciplines. Future development of the model will best be served by increased inputs from these diverse disciplines. Derivation of present and expected physical production relationships between inputs and outputs especially need information from a broad group of sources.

Production functions, although often difficult to estimate using standard statistical procedures due to multi-colinearity, are more easily understood than most alternative mathematical descriptions used to reflect the input-output relationships because of the direct relationship between independent variables and the dependent variable in each equation. Although changes in technology over time often rapidly decrease the validity of production function parameter estimates, the impact of technology can be integrated into the production functions with input from indiividuals knowledgeable in the productive process involved. The acceptability of a production function modeling method to a broad based clientele was the significant criterion in the selection of production function based modeling in this study.

Selection of Algebraic Form

There are several algebraic forms of production functions which can be used. The ones most commonly used are: Cobb-Douglas, Spillman, Quadratic, Power, and Square Root Functions. Many factors should be considered in order to select the appropriate functional forms. Criteria for the selection of functional form include ease of fitting and manipulating, ability to get a good statistical fit, empirical evidence, and economic theory. In this study, the Cobb-Douglas type function was chosen. The Cobb-Douglas function, historically, has a good statistical fit track record[6] and is probably one of the easiest to fit and

---

[6] Earl O. Heady and John L. Dillon, Agricultural Production Functions, (Ames, Iowa: Iowa State University Press, 1960), pp. 73ff.

manipulate. Marginal physical and marginal value products for each factor input are easily estimated.[7] It has the form:

$$Y = a \prod_{i=1}^{n} X_i^{b_i}$$

where, Y is the quantity of output, X_i is the quantity of the i^{th} input, n is the number of inputs, a is the constant multiplicative coefficient, and b_i is the exponential coefficient for the i^{th} input. The marginal physical product of an input is the partial derivative of Y with respect to that input. Conceptually, it is the amount of increase in Y caused by a one unit increase in this input if the impact of the one unit increase is the same over the one unit range as it is at the point where the derivation is taken. Methematically, the marginal physical product of the j^{th} input (MPP_j) is:

$$MPP_j = \frac{dY}{dX_j} = \frac{b_j a \prod_{i=1}^{n} X_i^{b_i}}{X_j}$$

The value of marginal physical product is the marginal physical product multiplied by the price of the output. Although a change in output creates a change in the price of that output, the decision makers are many and each decision maker's contribution to the total output is small enough that the marginal impact on output prices is ignored in the decision process. But since decision makers are aware of the decision of other decision makers, it is assumed that they react to expected impacts on market price of general statewide production plans.

---

[7]Lee, Y. C., "Adjustment in the Utilization of Agricultural Land in South Central Michigan with Special Emphasis on Cash Grain Farms," (unpublished Ph.D. dissertation, Michigan State University, 1975), pp. 40ff.

In the model, constant returns to scale are assumed by constraining the sum of the b's in each production function to be equal to one. This concept is based, in part, on the laws of conservation of matter. When the sum of the exponential coefficients in each production function is equal to one, Cobb-Douglas functions are homogeneous to degree 1. This means that if inputs are measured properly and all inputs are included, a doubling of all inputs to any production process will double the output.

In the relevant range of production, decreasing marginal returns to the increased use of an input while other inputs are fixed is assumed. With a Cobb-Douglas function which is homogeneous to degree 1, the fixing of any factor creates decreasing marginal returns to the remaining factors. Thus, the Cobb-Douglas production function meets the two major economic theory criteria proposed in this model.

Decision Making

The behavioral theory employed in the model, the equating of expected value of marginal products with the price of each input in each enterprise, was implemented by adjusting the quantity of each input used in each enterprise until the first derivative from the presumably known production relationship with respect to the input times the price expectation for the commodity produced was equal to the price of that input. The adjustment process used is described in the following chapter.

The expected production derived from the adjustment process is multiplied by a weather factor for each crop activity each year to estimate actual production.

A study by Glenn Johnson, et al.,[8] indicates that most farmers, in organizing the production on their farms, tend to center their organizational process for each enterprise around one of the more fixed assets or productive factors on their farms. This factor is càlled the organizing factor. Acres of land devoted to each crop and livestock physical capacity for each livestock category dominated in the decision making by farmers in that study. To reflect this characteristic, the model holds all input quantities except the organizing factor, fixed at the level simulated for the previous year while it estimates land use and livestock capacity for each year. With the exception of potato and sugar beet land, which are exogenous to the model, the component first equates the expected value of marginal product of land among the crop activities in a manner which will use all of the land available for agricultural crops. Corn and wheat diverted acreages are subtracted from these estimates. Then the model determines the livestock physical capacity in each livestock category by allocating commodity fixed capital inputs to their respective livestock enterprises at a level that will equate the value of marginal product of that input with its cost as obtained from their price-quantity schedules. Since expansion of livestock physical capacity is relatively expensive and alternative uses of most livestock facilities rather limited, the supply schedule for commodity fixed capital inputs are highly inelastic. After the organizing factors are allocated, the algorithm solves for the quantities of all the other inputs at the same time.

---

[8] Glenn L. Johnson, et al., Management Processes, p. 62.

CHAPTER 5

SIMULATION MODEL

Since computer based simulation models are written using computer science technology which is based on mathematical logic, their description tends to be difficult. In an effort to maintain clarity, the economic logic of the model has been presented in the preceding chapter. The description in this chapter is mechanistic and intended for those interested in the details of the mathematics of the algorithmic solution process required by the economic logic of the model. First, the mathematics of the production component algorithm is presented. Then the changes to total model are described with special emphasis given to the variables used by, but exogenous to, the production component.

Mathematics of the Production Component Algorithm

The component is a simulation of the production behavior of the Michigan agricultural sector over a multi-period time horizon. The mathematical problem to be solved in this component is as follows. Given: (1) the supply, expected demand, the actual demand functions; (2) the Cobb-Douglas production functions; (3) the quantity of land available for cropping; (4) the number of dairy cows; and (5) the impacts of weather; determine: (1) the demand for inputs by each enterprise; (2) the total demand for each input; (3) the expected price of each output; (4) the actual price of each output; (5) the price of each input; (6) the expected quantity of production of each output; and (7) the actual quantity of these outputs. This determination process is carried out in two steps. The first allocates land to each crop activity and enterprise capital to each livestock enterprise using historical information on output expectations and expected prices. The second determines the quantity of each input used in each enterprise by solving the following set of simultaneous equations. The production functions are represented by:

$$Y_i = A_i * \prod_{j=1}^{n} DEMINP_{ij}^{B_{ij}}$$

where:

$i = 1, 2, 3, \ldots, m$ and indicate activity

$j = 1, 2, 3, \ldots, n$ and indicate input category

A_i and B_{ij} are production function coefficients

Y_i is expected output

$DEMINP_{ij}$ is an amount of the j^{th} input used in the i^{th} activity

The total demand for each input category (TDEM) is:

$$TDEM_j = \sum_{i=1}^{m} DEMINP_{ij}$$

The price of each input category (PRINP) is:

$$PRINP_j = f(TDEM_j)$$

The expected price of each output (EPY) is:

$$EPY_i = f(Y_i)$$

And the behavioral assumption that input price (PRINP) is equated to its value marginal product (VMP), is implemented by:

$$PRINP_j = VMP_{ij}$$

The solution of this set of equations maximizes the implicit objective function:

$$\Pi = \max \left(\sum_{i=1}^{m} Y_i EPY_i - \sum_{j=1}^{n} TDEM_j PRINP_j \right)$$

The Cobb-Douglas programming equations above parallel the equations in Linear Programming in several ways. There is one production function for each activity. The summation of each column in the DEMINP matrix equals total use of an input and is constrained by its input price schedule ($PRINP_j$). The expected gross income per unit of expected output from each activity is specified by the output price functions (EPY_i). The objective function is forced to its maximum by the final equation. Vertical integration of activities, say the use of corn in hog production, can be implemented by designating corn as one of the input categories and subtracting corn so used from the output of corn.

Technical Description

The production component was developed separately from the Michigran model. It is not iterative in itself but must be provided with input from the general model to iterate over time. Therefore, it was inserted into the Michigan Model; and necessary changes were made to accommodate it. The pertinent parts of the final model are described in this section. Some detail is left out when there is no change from the Michigan Model. The following descriptions are in the sequence found in the actual computer program. The order of execution within the model is explained in the description of subroutine MICMOD.

Program MAIN

The main program of the model, for simplicity, was named MAIN. This program was designed so the PAL package could be easily attached to the model. Therefore, the primary purpose was to initialize variables and call a subroutine named MICMOD.

Variables initialized in the MAIN program were selected on the basis of: (1) programming convenience, and (2) relevance as policy variables. The Cobb-Douglas production functions which determine the expected output of the 13 enterprises included in the model and the 24 inputs to these enterprises are programmed using a 12x13 matrix. Therefore, many variables are included as 12x13 matices. M was initialized to 13 for the number of products (rows) in these matrices. N was initialized to 12 for the number of inputs (columns) in these matrices. M and N are used throughout the program to perform matrix manipulations. The eleventh column designates enterprise specific capital and is treated as 13 separate columns in these manipulations.

MARG and NARG are each set equal to 4 and indicate the number of points specifying the price-quantity schedules of demand for agricultural commodities and supply of inputs, respectively. The price-quantity schedules are defined by linear interpolations between these points which are generated in the INSUP and OUTDEM subroutines. Although some modeling efforts may need more turning points than the two allowed by this value, this was sufficient for the present model. Human population variables initialized in MAIN are: (1) the initial farm and nonfarm population by sex by five year age cohorts, (2) the rate of change of the fertility rate of women in the population (RCFRTR), (3) the proportional rate of migration from farms (PMRFB), and (4) variables which allow adjustment of migration rates by the four age groupings, as in the Michigan Model. Variables related to the allocation of land initialized in the MAIN Program are: (1) per capita demand for land by farmers; (2) per capita demand for land by nonfarmers; (3) quantities of timber and noncrop land on farms; and (4) the constraint on the maximum allowable proportion of total land which is not in farming.

Major impacts of the economic environment on the agricultural sector are specified through supply schedules for the inputs used in agricultural production and the demand schedules for agricultural products. These price-quantity schedules are centered around expected total demand for inputs, actual prices at that expected demand, an historical quantity of production by the sector, and farmers' one-year expectation of price. The expected total demand and the historical agricultural production of the sector are initialized in the MAIN program for 1955.

The algorithm within the production component which solves the system of simultaneous equations requires a starting point. This starting point is specified by a 12x13 matrix, called demand for inputs (DEMINP). Since there is considerable uncertainty about the proper values of the production function coefficients, they are initialized in the MAIN program. The exponential coefficients (b_{ij}) are initialized as a 12x13 matrix. The multiplicative coefficients (a_i) are initialized in a 13 element array. Two arrays initialized in MAIN identify the rows and columns of the matrix, where the rows are the products of the production component and the columns are the inputs. The row labeled array (RLABEL) includes the 13 products: corn, wheat, dry beans, soy beans, potatoes, sugar beets, hay, milk, beef, hogs, eggs, horses, and others. The column label array (CLABEL) specifies the 12 input categories. These are: fertilizer, dairy cows, durable capital, expendable capital, feed grain, hay, soy, tractors, combines and pickers, labor, enterprise specific capital, and land. The foregoing labels, while not adequately reflecting the categories, do act as indicators of the categorizations.

Subroutine MICMOD

This subroutine is an executive routine which controls the execution of the model. It is designed according to the specifications of the computer library document, SIMEX1.[1] This document should be referred to for general comprehension of the routine. The remainder of this section delineates the divergencies between the subroutine MICMOD and the computer library program.

Development time and printing cost made the option for only two levels of model output infeasible. Additional options were created using the variable DETPRT from SIMEX1. It was retained as a selector of detailed printout but was no longer bivariate. There are five levels of detailed printouts available. The quantity of detailed printout is specified by the value given to the variable--each level includes the detailed printing of all values of smaller magnitude than itself. If DETPRT is equal to 0, there is no detailed printing; if it is equal to .5, there is a detailed printout of all variables in the detailed printout listing; if it is equal to 1, there is a dumpout table of the Cobb-Douglas programming tableau and the solution values by the algorithm for each time to be printed (TPRT); if it is equal to 1.5, the largest error found during each loop of the algorithm is printed; and

[1]Chris Wolf, Thomas J. Manetsch and Claudia Winer. "A FORTRAN Executive Program for Continuous Flow Simulation Models--SIMEX1," Training Program Paper, East Lansing, Michigan, 1974.

if it is equal to 2, each value used in the algorithm is printed out for each adjustment made in the solution process.

The specification of time interval between printouts and its change point has been replaced by the specification of the number of times to be printed (NPRT) and the years of those times (TPRT) as was indicated in the preceeding section. This adds a great deal of flexibility to printing options, while placing an upper limit on the number of print times to insure compatability with the subroutine which prints the selected output. The other major divergence from the computer library documentation is that the option to make more than one run per execution has been removed.

The only parameters initialized in subroutine MICMOD other than those for duration of the simulation run, time increment per simulation cycle, and printout variables, are the titles for the selected printout tables.

Subroutines called by MICMOD are called in each year of the model run in the following order.

1. POPULN simulates the present and lagged human populations for farms and nonfarm.

2. LVSPOP models the trend in livestock populations.

3. LAND calculates land available to agriculture and trends in land use within agriculture.

4. PRODCN models expected yield per acre of land for the various crops and per head for the livestock enterprises. This subroutine also simulates input suppliers expectations of the sectors demands for fertilizer, expendable capital, and livestock feed.

5. INSUP specifies the supply schedules for inputs to agriculture.

6. OUTDEM specifies the demand schedules for agricultural products.

7. CDPROD models the production behavior by determining the input and output quantities.

8. ACCENT performs the accounting operations to calculate total figures for the sector.

9. PRINTS stores and prints the model results for the selected output table, for the years which need to be printed out.

Subroutine POPULN

This subroutine initializes fertility, death, and interstate migration parameters, plus other necessary values for the demography subroutines, then calls the demography subroutines. No changes were made in the population subroutine from the Project 80&5 model, with the exception that the initial lagged population used, in the demand for land subroutine was lowered to reflect 1955 population levels. Results from this subroutine are not highly accurate for the 1955 to 1962 period, but the level of discrepancy has a negligible impact on agricultural production.

Subroutine LVSPOP

Livestock numbers (POPLS) produced by this component are dairy cows; expected linear trends for beef slaughter, hog slaughter and laying hen population; and demand for horses. The number of dairy cows is modeled using a demographic utility routine. This routine is the same as in the Michigan model. The only changes made in the parameters used for determination of dairy cow population are the initial population, which is initialized at 1955 levels and a multiplicative value used to adjust the cull rates for the dairy cow population (CULLR). This multiplicative adjustment is equal to the per head costs incurred in producing milk (COST) divided by the gross income per head (GYPU). Beef, hog, and laying hen numbers are estimated by linear interpolations between trend values corresponding to 1955 and 1962. These trend values are exogenous pending development of an expectations model. The apparent reversal of horse population during the time period modeled resulted in an ad hoc determination of horse population being the maximum of .04 - .002*T and .02 + .005*T with T being time in years starting from zero at the beginning of the model run (1955).

Dairy cow population is used by the production component (CDPROD) as an exogenous variable. All livestock populations produced in this component are used by the production expectations component (PRODCN) for modeling market channel capacity.

Subroutine LAND

The total land available for agriculture crops (AGLAND) is determined by subtracting the demand for nonfarm land (DEMNFL) and farm demands for land other than crop land (DEMLNDF) from the total land area of Michigan (TLND). Farm demands for land other than crop land is modeled by a table function. This land is animal housing, timber land, and land too rough for cropping. The quantity variable, which is plotted against time, is called VTIMBER. This quantity is held constant at 6 million acres. Expected agricultural crop land for each crop is determined by time trend changes in proportion multiplied by agricultural land available for cropping. These proportions vary linearly with time. It should be noted here that pasture land for horses, cattle, etc., is considered crop land and is included under the "other" category. The LAND component also divides total crop land by total farm population to calculate a per capita agricultural crop land figure.

Subroutine PRODCN

Expected yields per basic unit of each enterprise (acres for crops and head for livestock), in the initial year (VYLD(1)) and end year (VYLD(2)) of the model run are used to determine expected yields (EXYLD) for all years of the model run by linear interpolation. Expected total production (EXPROD) is derived by multiplying the expected yields by their respective basic unit quantities expected (CRPLND and POPLS). The per unit expected demand (RINP) for each of the five inputs included in this component are estimated using the equation:

$$RINP_{ij} = RINPS_{ij} + RRINP_{ij}*T$$

where:

T is time with 1955 represented by 0

$RINP_{ij}$ is the per unit expected demand for the j^{th} input in the i^{th} enterprise at time T

$RINPS_{ij}$ is the per unit expected demand for the j^{th} input in the i^{th} enterprise at the start of the model

$RRINP_{ij}$ is the expected change per year in the per unit demand for the j^{th} input in the i^{th} enterprise

i indicates the enterprise, with the 13 enterprises being in their normal order

j indicates the input category, with fertilizer, expendable capital, soy, feed grains, and forages being represented by j equal to one through five, respectively.

Expected demand for each input by each enterprise (EXINP) is estimated by multiplying per unit demand for inputs by the respective expected unit quantities. Total expected demand for each included input (EXDEM) is derived by adding the EXINPs across enterprises.

Subroutine INSUP

Input supply schedules for the inputs to the agricultural sector are defined by four points and linear interpolations between those points plus linear extrapolations past the end points. A reliable quantitative estimation of these supply functions is beyond the resources of this study. It would involve the determination of 24 supply functions of inputs categories which are each aggregations of a complicated set of inputs. Determination of these supply functions is greatly complicated by the wide range of quantities necessary in each function and the omnipresent differing degrees of asset fixity among the inputs. In addition, most data series record only one price for inputs with little indication of the relation of this recorded price to either salvage or acquisition prices.

Ten of the inputs, all but dairy cows and enterprise specific capital, are considered fixed to at least some degree to the agricultural sector although completely fluid to shift between the enterprises within the agricultural sector using that input. This assumption fails to recognize the reality of transportation and transfer costs of inputs within the agricultural sector, since most enterprises are regionally concentrated within the state. The seriousness of this failure is uncertain, but the assumption is common in most input-output or linear programming macro-models of any sector even though it may have many managerial units and occupy enough space to create transportation costs. The remaining 13 inputs are labeled enterprise capital and are specifically fixed to the enterprise. Pricing of these 13 inputs is very difficult because they should include the value of the human capital required for implementing agronomic and husbandry practices specific to the enterprise. It should also reflect the cost of gaining additional information to improve decision making, otherwise the model will implicitly assume static quantities of human capital.

Beginning values for the total expected demand for all inputs in the first year of the model run are initialized in INSUP as total demand values (TDEM). These quantities are used as a basis for determining the quantity arguments in the supply schedules during the first year for all inputs except the five expected demands (EXDEM) calculated in PRODCN. In the other years of the model run the total demands for inputs used in the immediately preceding year (T-1) are used as a basis. Arguments for the quantities in the input supply functions are determined by multiplying EXDEM, or TDEM for inputs for which EXDEM does not exist times a constant multiplicative factor (see Table 2). This procedure determines the four quantity arguments for each input.

Input prices (PRINP) corresponding to the EXDEM or TDEM quantities are derived by multiplying the base price of the input (BPRINP) times an annual index price (APRINP). Price arguments corresponding to the quantity arguments described in the preceding paragraph are determined by multiplying PRINP times constant multiplicative factors (see Table 2).

Subroutine OUTDEM

The price elasticity of demand for most agricultural products of Michigan is, *ceteris paribus*, infinitely elastic, with the exception of the impact of institutional marketing channel constraints. If *ceteris paribus* is not assumed and perfect correlation between production and operation of the market in Michigan and the rest of the United States is assumed, the elasticity of demand is the same for Michigan as for the nation, exclusive of institutional and transportation constraints. The model assumes the trend in production of agricultural products establishes an inertial force in the marketing channels. The relevant price on the output price-quantity schedule corresponding to this production quantity is assumed to be farmers' one year price expectations.

Table 2: Constant Multiplicative Values Used in the Determination of Quantity and Price Arguments for Input Supply Schedules ($ARGT_{ij}$) and ($ARGPIN_{ij}$)

i^{th} input*	j^{th} Point							
	1		2		3		4	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price
1,4,7	.00	.80	.90	.95	1.10	1.05	2.50	1.20
2,3,8,9	.50	.20	.85	.30	1.15	1.70	1.50	1.90
5	.75	.90	.96	.95	1.00	1.00	1.05	1.05
6	.50	.50	.95	.95	1.05	1.05	1.50	1.20
10	.50	.80	1.00	1.00	1.05	1.50	1.50	2.10
12	.75	.20	.96	.60	1.00	1.00	1.05	1.40
13 through 25	.20	.20	.70	.30	.90	.98	1.10	1.02

* The inputs index numbers are presented in the same order as found in the model. It is as follows:

1. fertilizer
2. dairy cows
3. durable capital
4. expendable capital
5. corn
6. hay
7. protein feeds
8. tractor
9. combines and pickers
11. labor
12. land
13-25. enterprise fixed capital

Actual prices received by farmers (PRP) differ from expected prices (AEPY). Both are initialized in program MAIN for each year and product. The production level resulting from the trend as modeled in PRODCN and the expected commodity price combine to define one point on the price-quantity output demand schedule for each commodity. This subroutine generates four points for each demand schedule. A linear interpolation between these points and extrapolation past the end values of these points defines a continuous demand function for each output. The present model initializes all demand functions using the same multiplicative values for all commodities. The four multiplicative values used to generate the quantity arguments are: .01, .6, .9 and 1.4 for arguments one through four, respectively. The corresponding multiplicative values used to generate price arguments are: 1.22, 1.12, 1.02 and .92.

Subroutine CDPROD

The production subroutine determines the input and output quantities of production in the agricultural sector model through an algorithm which equates the marginal value product of inputs with the prices of those inputs. The algorithm begins with the demand for inputs of the previous year or, in the case of the first year, the demands for inputs as initialized in program MAIN. The algorithm begins with the determination of quantity of land in each crop. This is done by calculating the value of marginal product of land at last year's level of production using last year's allocation of land for each enterprise and the expected price of the product in the present year. A weighted average value of marginal product (WAVMP) is determined by taking an average of the value of marginal products described above and weighting them by the quantity of land used in each crop. The demand for the input land is then estimated for each crop by using the b value for the land input in each enterprise times the production in the previous year times the expected price of the product in the present year divided by the foregoing specified, weighted average value of marginal product (WAVMP). The total demand for land is then calculated by summing the allocation of land to each crop. The allocation of land to individual crops is then adjusted to made the total demand for land equal to the amount of land available for crops as determined in subroutine LAND. This is done by adding to the allocation of land to each crop a quantity equal to the difference between land available for crops and the total demand for land times the inverse of a derivative of the VMP of land in each enterprise with respect to land divided by the sum of these derivatives across all enterprises. This ensures that the total demand for land is equal to the agricultural land specified in subroutine LAND.

This subroutine then moves on to the algorithm process of allocating the other inputs and estimating the outputs of the production functions. The algorithm requires the initialization of two variables in addition to those already initialized. These are the maximum allowable error and the limit on the number of iterations allowed in the solution process. Although the limit on the number of iterations is not constraining in the present model, it ensures that excessive computer costs are not created by slow convergence to the solution. The maximum allowable error is initialized as .025 and the limit on number of iterations is 110.

Each iteration of the algorithm begins by calculating the total demand for each input by summing the individual quantities of the input used in each production activity. The price of each input is derived from its respective supply schedule. Expected production is estimated next using the Cobb-Douglas production function. It is called expected production because it does not include the input of weather. Next, expected commodities prices are calculated from the demand schedules. The value of marginal product (VMP) of each input in each enterprise is calculated using the b value times the expected production time the expected commodity price divided by the input quantity allocated to that activity. The error for each input is determined next as being the absolute value of the difference between the calculated VMP and the price of the input divided by that price. If all errors are less than the maximum allowable error, the algorithm is considered solved and no adjustments are made in the allocation of inputs. If at least one error is greater than the maximum allowable error, the algorithm first adjusts the quantities of the input allocations which have the largest error. This is done by adjusting those with errors greater than .125. If none are greater than .125, the level of checking is reduced by dividing the check level by 5. This means the check level would move to .025, which is equal to the maximum allowable error. The algorithm adjusts all errors greater than the check level. This is done by adjusting the input quantity by adding to the demand for input the result of the division of the difference obtained by subtracting the marginal value product from the price of the input by the difference between the derivation of the VMP with respect to the input minus the slope of the supply function for that input.

In certain cases, this adjustment process overcompensates for the error to the point where the input quantity becomes negative. Therefore, the adjustment in the demand for an input is not allowed to be greater than 60 percent of the demand for that input in each iteration. An adjustment factor is multiplied times the additive adjustment to ensure against overadjustment: (1) when most errors of the input to one enterprise are of the same sign, and (2) to ensure against over adjustment when the use of one factor is adjusted in several enterprises at the same time. After the allocations of all inputs with errors greater than the check level are adjusted, the algorithm begins its next iteration. The iterations continue until all errors are less than the maximum allowable error, or 110 iterations have been completed.

At the conclusion of its final iteration for each year, the algorithm has solved for all of the output variables of the production component except the final estimate of total production for each crop, estimated yield per acre of crops and estimated price received for all commodities. The expected production of each crop as calculated in the algorithm is multiplied by a crop and year specific weather index (SINDX) to get the simulated actual production quantities. These quantities are divided by their respective land allocations for the year to estimate yields per acre. The subroutine determines the estimates for the prices actually received by adjusting expected commodity prices calculated in the algorithm by the difference between the expected (AEPY) and the actual (PRP) national price levels initialized in program MAIN (see Appendix A for the values of these variables).

Additional Subroutines in the Model

The remaining subroutines in the Michigan Model remains the same in the MASS model, except the adjustment in the number and titles of the input and output categories. Two minor subroutines were added, a table look-up function which interpolates between the points on the price-quantity schedules and a print routine which displays the annual results of the algorithm in CDPROD.

In conclusion, the major changes to the structure of the model were the addition of the new production subroutine, subroutines generating determinate points for the supply and demand schedules, and the shift of the old production subroutine to a trend indicator of marketing channel capacities. The major changes in model data and parameters were those added by the additional model structure and by the initializing the model to start from 1955. Minor changes to the land allocation decision rules were made to determine their impact on the model's ability to track the performance of the system modeled, these will be described in the following chapter.

CHAPTER 6

MODEL RESULTS AND ANALYSIS

Chapter 4 specified the economic model and its structure. Chapter 5 described in detail the computational process that was implemented. The project results and their implications are the topic of this Chapter. It is divided into three sections. These sections are: (1) a description of model runs, (2) empirical accuracy analysis of model output, and (3) a discussion of the implications drawn from model structure and model output.

Model Runs

The model described in the preceding chapters is sufficiently complex to make the tracing of sources of error impossible. If the structure of the model was reducable to a combination of linear models, sources of error could be traces using statistical analysis or optimal control theory. During the time the Cobb-Douglas programming algorithm was being designed, much fruitless effort went into finding a reduced form for the simultaneous equations. A reduced form would allow an analytical solution instead of the present numerical solution in addition to making the tracing of sources of error possible. Some general conclusions, however, are possible. These come from familiarity with the model coupled with experimentation. Sources of error can be divided into three classes, (1) structural errors, (2) parameter or data errors, and (3) programming errors. Three runs in addition to the basic model run were designed to indicate sources of error.

The first experiment constrained model behavior by injecting information about the actual land acreages allocated to crops and the level of technology actually used in each enterprise to determine the contribution of the lack of accuracy of these variables to model tracking errors and check for programming errors. The tracking errors of this constrained run also indicate the aggregate influence of any other structural or data and parameter errors in the model. The greatly improved performance of this constrained run coupled with the fact that technology level is exogenous to the model, motivated two experiments with the land allocation decision rules. The simulated production levels of the thirteen commodities for the eight years of all four model runs in addition to actual Michigan production levels are presented in graphical and tabular form in Appendix B.

Basic Run

This run is without any deviation from the description in the previous chapters. The basic model assumes there is a trend toward equating the value marginal product of land among crop activities. The inclusion of only one land category makes an implicit assumption of homogeneity of all land.

Constrained Run

The model was run with both actual land planted to each crop (ACRES) and estimated level of technology for each enterprise entered exogenously. Actual land planted to each crop was entered each year of the model run and the production component was not allowed to change this quantity. The estimated level of technology for each enterprise (AA) was entered as the multiplicative constant in each Cobb-Douglas production function instead of the linear function of time coefficient used by the basic model. The estimation process used to determine these values and the values used are presented in Appendix A. Model output from this run is much closer to actual performance observed in the sector than output from a basic model run.

The close tracking of the constrained model run to actual production in Michigan indicated that any structural, parameter, data or programming errors in the model, except in technology estimation or land allocation processes were either insignificant or counter balancing. Computer calculations of this model run were printed out in detail and checked using a hand calculator. No errors were found in this process.

The results of the constrained model run imply that considerable improvement in model performance can be attained through improvements in the structure of the model in land allocation and technology level estimation. Alternatively, performance could improve from use of better parameters and data in these areas. Developments in structure, parameters and data tend to be more complementary rather than mutually exclusive, so it is probably not important to determine which area of further development would be most fruitful. The level of technology used in each enterprise is exogenous to the production component, while land use is central to the component. The other two experiments were designed to test alternative land allocation rules.

<u>Complement Run</u>

This experiment maintains the principle of equating the value of marginal products of land among crops, but assumes that farmers maintain perfect complementarity between land and three other inputs during their land allocation decision and relax this complementarity constraint after deciding crop acreages. These inputs are fertilizer, expendable capital and labor. This complementarity was assumed to be in the proportions the inputs were used in the previous year and the model maintains the assumption only through the land allocation stage of the model. These inputs are allowed to vary in the same manner as in the basic run after land allocations are made. The land allocation process is executed by calculating the value of marginal product of this group of inputs (VMP) for each crop using the equation:

VMP = BDUM*YLD*EPY

where:

BDUM is the sum of the exponential coefficients corresponding to fertilizer, expendable capital, labor and land

YLD is the expected per acre yield of the crop in the previous year

EPY is the expected price of output in the present year.

The per acre cost of the inputs complementary to land is subtracted from this calculated VMP. And the resulting values are moved toward equilibrium by the same method used in the basic run.

Constant VMP's Run

This experiment did not assume the value of marginal product of land moves toward equilibrium among crops. It assumes that the allocation of crop land among crop enterprises is dependent upon changes in price and yield expectations. Price expectations are the same as in the basic run of the model. Changes in yield expectations are derived from the PRODCN component. The value of marginal product of land in each crop is equated to the value marginal product in the previous year taking into consideration the expected changes in price and yield using the equation:

$$DEMINP(12) = \frac{OLDYLD*OLDEPY - DINTER*EXYLD}{DSLOPE*EXYLD^2}$$

where:

DEMINP(12) is the quantity of land allocated to the crop

EXYLD is the expected yield per acre in the present year

OLDYLD is the yield per acre expected in the previous year, that is, expectation before weather impacts are included

OLDEPY is the price of output which would have resulted without the disturbance of weather on yields

DINTER and DSLOPE are the intercept and slope, respectively of the relevant portion of the expected demand schedule for the output.

Since the sum of the estimated quantities of land will not add up to the total amount of land available the adjustments made by the basic model are implemented. These adjustments shift land use in a manner that will change the value of marginal product of land in each crop by the same absolute amount.

Results of all model runs and the performance of the sector are presented in Appendix B. The remainder of this chapter discusses and evaluates model performance.

Empirical Analysis of Model Outputs

At the present time, there is considerable controversy over what constitutes a proper validation process for a method of projection which encompasses many variables and events. Fundamental to this controversy is the question of what constitutes the basis of comparison. For models which are developed after the time they are constructed to reflect, another important question is: "To what degree and what constraints should be placed upon the use of information available only after the initial year modeled?" Especially in a situation where a model developed for the purpose of tracking historical events and has no peers in terms of the events included in the model output, the question reduces to, "What is a sufficiently accurate model?" Of course, a model which exactly tracks the historical course of events is ideal. But, if model outputs include many variables for which no observations exist for the time period tracked, even this basis of comparison is impossible.

The model to be evaluated here simulates behavior from 1955 through 1962. It is a production component that is integrated into a model of Michigan's agricultural sector. It can be perceived as having over 200 outputs for each year, 156 of these outputs are the elements 12x13 matrix. The values in this matrix quantify the inputs to 13 enterprises and aggregate to 24 different inputs used in the agricultural sector. Each input and output has a price connected to it. These prices are variants from U.S. prices, a variance which is dependent upon the degree to which the quantity differs from historical levels or trends. It is not pretended in this project that accuracy of all of these outputs can be measured with respect to tracking ability. Even if such a task were feasible, it would be impossible to compare the accuracy of 200 statistics without considerable aggregation. The 200 variables all play roles in determining the quantity of output produced in each enterprise in the state, therefore, model validation has been restricted to the ability to track output for the 13 included enterprises.

Four empirical methods of evaluation are included: (1) proportional error, (2) correlation analysis, (3) turning point analysis, and (4) Theil's U coefficient.

Observation of graphical and tabular representations of model output has many advantages in comparison to most empirical methods because of the ability to include perceptions about the relative importance of errors among different variables that are difficult to quantify in a single empirical evaluation process. But the subjectivity of observation creates a difficulty of explaining the basis of insights gained through observation. For that reason, the graphs of model output for the 13 enterprises from 1955 through 1962 and their corresponding actual values are included in Appendix B.

Proportional Error

One of the simplest and probably most easily understood statistics about the accuracy of time series outputs of a simulation model is the absolute value of proportional error. In table 3, two statistics of the absolute proportional error are included for each time series of each run of the model. These two statistics are the average of the absolute values of the proportional erros (AVEPE) and the proportional error with the largest magnitude (MPE) that occurred in the time series. The absolute value of the proportional error is calculated as follows:

$$PE = \frac{|P_t - A_t|}{|A_t|}$$

where:

P_t = the simulated value at time t

A_t = the actual value at time t.

Table 3. Average and Largest Absolute Values of Proportional Errors

	Basic Run		Complements		Constant VMPs		Constrained	
	AVEPE	MPE	AVEPE	MPE	AVEPE	MPE	AVEPE	MPE
Corn	.1079	.1943	.1520	.2258	.0575	.1258	.0267	.0609
Wheat	.1155	.2125	.1478	.2669	.2068	.3145	.0282	.0510
Dry Beans	.0842	.1638	.0970	.2073	.2088	.3119	.0188	.0380
Soy Beans	.1011	.2687	.0989	.2676	.1061	.3086	.0207	.0431
Potatoes	.1259	.6063	.1255	.6157	.1265	.5969	.0460	.0798
Sugar Beets	.0406	.0643	.0436	.0718	.0375	.0605	.0297	.0728
Hay	.0907	.1680	.1378	.2607	.0896	.1885	.0179	.0312
Milk	.0509	.1734	.0507	.1714	.0520	.1784	.0115	.0244
Beef	.1373	.3133	.1371	.3153	.1377	.3131	.0289	.0518
Hogs	.0529	.1175	.0549	.1232	.0531	.1228	.0235	.0466
Eggs	.1012	.2012	.1012	.2012	.1033	.2026	.0229	.0424
Horses	.0177	.0324	.0176	.0321	.0178	.0318	.0067	.0208
Other	.0631	.1175	.0886	.1456	.0827	.1983	.0063	.0165
SUMMARY	.0838	.6063	.0964	.6157	.0984	.5969	.0221	.0798

And the average of the absolute value of the proportional error is calculated as:

$$AVEPE = \frac{1}{n} \sum_{t=1}^{n} \frac{|P_t - A_t|}{|A_t|}$$

The maximum proportional error is simply the largest value for absolute proportional error encountered in the time series. The bottom row, or summary row of the table includes the average of the column above it for the average proportional error and the maximum of the column above it for the maximum error. These two statistics should be interpreted as the average proportional error for the 13 model outputs and the largest error in the model for the 13 outputs respectively. Thus, under the assumption of equating the weighted average value marginal product (WAVMP) the average value of the absolute proportional errors is equal to 8.38 percent.

Analysis using the absolute values of the proportional error provides a first rough indication of the accuracy of the model output. The maximum values give a general indication of the range of errors. It also provides indicators of the most significant projection problems of the model and indicates directions to look for sources of error in the model. For example, the maximum error in all model runs is the porportional error in the projection of quantity of potatoes produced. Sources of this error calls for close scrutiny. This is true especially because, in the basic model run, a sole change to an accurate projection of potato production in the year in which the largest proportional error occurs would lower the average proportional error in the prediction of the production of potatoes by considerably more than half and would reduce the average error over the total model by slightly more than one half of 1 percent. The graph of actual and predicted production of potatoes in Appendix B indicates that the maximum error occurs in 1960 in all three of the unconstrained models. In all models, the land used for potato production is exogenous and decreases from 1959 to 1960; but projected production nearly doubles in all three of the unconstrained models in that one-year period. Appendix A indicates no significant changes in the prices of inputs or in the weather index for those years. There is an increase by approximately one fourth in the expected price of potatoes. It seems reasonable to suspect the expected price series or the elasticity of supply of potatoes implicit in the model. The evidence that less land was planted to potatoes in 1960 than in 1959 raises the serious question about the applicability of the Lerohl's national one-year expected price of potatoes to the Michigan agricultural sector. These expected price estimates were maintained in the model because no alternative expected price series exists for Michigan potato market. The suspicious character of the expected price series does not exonerate the problem of the elasticity of supply of potatoes in Michigan however. It seems unreasonable that a 25 percent increase in the expected price of potatoes should create a nearly 100 percent increase in the production of potatoes given a decrease in land and no significant change in weather factors. This type of shift implies a supply price elasticity of approximately four and a physical doubling of per acre yields in a one-year period. The first is questonable and the second is unreasonable in terms of physical capabilities alone. There are two related probable sources of difficulty: (1) the lack of sufficient complementarity of inputs being reflected in a Cobb-Douglas production function and (2) improper specification of asset fixity in the inputs to potato production. The second probable source includes both possible improper aggregation of inputs and specification of the supply schedules of the inputs as presently specified in the model. A standout in this category is the high price elasticity (approximately five) of the input specialized to potato production when this input is expanding beyond the level used in the previous year. Subjectively, this elasticity is not considered unreasonable in the immediate range about the previous year's level, but it is questionable when there is a significant expansion in the use of this input. Specification of an additional turning point in the supply schedule of this input would require a complete reprogramming of the production, input supply, and output demand components of the model.

The average proportional errors also give an indication of the relative merits of the three unconstrained models and the accuracy in the constrained run. The summary average under the assumption of equating the weighted average value marginal product of land is more than 10 percent less than in the other two unconstrained models. In addition, this run of the model has or is within 10 percent of being the lowest average proportional error in 11 of the 13 individual time series outputs.

Correlation Analysis

The correlation between actual and projected quantities of production provide a second method of quantifying the characteristics of model output. Their unique strength among the empirical methods used in this evaluation is their ability to reflect shifts that proportionately move in the same direction with respect to time periods.

The analysis of a model's ability to track through the use of correlation coefficients (see Table 4) has a serious weakness in that the coefficients obtained only indicate the linear relationship between the projected values and the actual values. This means that it can only indicate the ability of a linear equation reflecting the relationship between the actual and projected values. The correlation coefficient squared reflects the ability of the projected value to explain the variance in the actual value about its mean. The results from this analysis are not considered to be indicative of the model's validity but it is included to allow those interested to gain a perception of the problem of model validation through this type of analysis.

The correlation coefficients for dry beans, soybeans, sugar beets, and horses are quite high for all models. The negative correlation coefficients in corn, milk, and eggs, reflect an overall opposite direction in trends in actual and projected output values. The negative correlation found in eggs and milk are a result of model structure and the occurrence of the highest expected prices for those commodities in years of low production quantities. The negative correlation was forced upon the model by the assumption of linear relationship between time and changes in technology. It is suspected that the negative correlation found in corn and the low correlation coefficients for wheat are a result of the ad hoc method of including corn and wheat programs as a factor in determining land inputs in these two crops. The low correlation coefficient found in potato production is a result of those same factors that caused large proportional errors as discussed in the previous section.

Table 5. Correlation Coefficients Between Projected and Actual Production for the Four Model Runs

	Basic Run	Complements	Constant VMPs	Constrained
Corn	-.1864	-.6833	.8196	.9791
Wheat	.4426	.1590	.1821	.9951
Dry Beans	.9786	.9802	.9688	.9961
Soy Beans	.9270	.9329	.9160	.9958
Potatoes	.5887	.5920	.5686	.9893
Sugar Beets	.9949	.9933	.9953	.9941
Hay	.6712	.5578	.6493	.9778
Milk	-.5491	-.5407	-.5407	.8655
Beef	.5159	.5229	.5137	.8525
Hogs	.7286	.7081	.7158	.8688
Eggs	-.0203	-.0237	-.0194	.9884
Horses	.9938	.9938	.9946	.9977
Other	.9198	.9411	-.4272	.9879

Turning Point Analysis

Turning point analysis is used in this evaluation to indicate a procedure of analysis of the model's ability to predict turning points in the change in actual values over time. A significant problem in projection is the ability to predict turning points. For variables that have a constant trend with no turning points, the value of forecasts tend to be relegated to a determination of how much expansion or how much reduction in capacity is needed for the projected time. Significant value in forecasts are the ability to predict changes in trend lines. For the purpose of this type of analysis, a contingency table was set up with bivariate rows and columns for the incidents of actual and predicted turning points. Thus, the contingency table has four cells. These four cells are: (1) predicting a turning point which actually occurred, (2) predicting a turning point which did not materialize, (3) predicting no turning point when a turning point did occur, and (4) correctly predicting no turning point. In a model of an eight-year period, there is a possibility of six turning points for each variable forecasted, one for each year excepting the first and last year. For each run of the model, with its 13 enterprises there will be 78 events included in the contingency table. A frequency count of the occurrence of the four separate events is entered into its respective cell. Entries in cells two and three represent failures. Following the procedure set by Theil,[1] these two errors shall be called turning point errors of the first kind and of the second kind, respectively. An error of the first kind is the prediction of a turning point when no turning

[1] H. Theil, Economic Forecasts and Policy, (Amsterdam: North Holland Publishing Company, 1965), p. 29.

point occurred and an error of the second kind is a prediction of no turning point when a turning point did in fact occur. Quantitative measures for the description of both types of failure used for this study will be the proportion of predicted turning points which turned out wrong (q_1) and the number of erroneous predictions of no turning point as a proportion of the total number of actual turning points (q_2). Standard Chi-square analysis was used to test the hypothesis that prediction of turning points are randomly distributed.

The information from the standard Chi-square contingency tables are presented in Table 5 in simplified form. In the first column, the number of turning points which actually occurred are entered (cell 1 plus cell 3). In the second column the number of turning points predicted is entered (cell 1 plus cell 2). In the third column the number of correctly predicted turning points is entered (cell 1). The Chi-square contingency tables from which the information in Table 5 was drawn can be recreated by simple arithmetic and the knowledge that there are 78 observations in each contingency table. The proportion of type 1 and type 2 errors occurring are presented as the quantities q_1 and q_2, respectively. The Chi-square test of significance far exceeded the .005 level for all model runs.

Another interesting observation from this analysis is that the type 2 error occurred much more frequently than the type 1 error in all of the unconstrained models. This implies that a higher proportion of the errors were of the case when no turning point was predicted but a turning point did occur. This is not a surprising result and can be traced to problems of insufficient information about the asset fixity of inputs to the separate enterprises and the assumed linear relationship between time and change in technology.

Table 5. Prediction of Turning Points

	Number of Turning Points					
	Actual	Predicted	Correctly Predicted	q_1	q_2	Chi-Square Significance Level
Basic Run	44	35	31	.1143	.2955	***
Complements	44	37	31	.1622	.2955	***
Constant VMPs	44	38	33	.1316	.2500	***
Constrained	44	46	38	.1739	.1364	***

*** indicates Chi-Square Significance at a probability level of .005.

Theil's U

Theil's U coefficient is calculated using the following equation.[2]

$$U = \sqrt{\Sigma(P_i - A_i)^2} \;/\; (\sqrt{\Sigma P_i^2} + \sqrt{\Sigma A_i^2})$$

where:

$P_1, \ldots, P_n$ are the simulated values

$A_1, \ldots, A_n$ are the corresponding actual outcomes.

The numerator of U is the square root of the second moment of the forecasting errors; the denominator is simply such that $0 \leq U \leq 1$. Except for the trivial case when all P's and A's are equal to zero, the coefficient U is confined to the closed interval between 0 and unity. When U = 0: $P_i = A_i$ for all i's. This is clearly the case of perfect forecasts. When U = 1, there is either a negative proportionality, or one of the variables is identically 0 for all i's.

The inequality coefficient (U), unlike the correlation coefficient is not invariant against additive variations. In other words, errors of the same absolute value in predicting a variable with actual value ranging from 0 to 10 would have a much larger inequality coefficient than these same absolute errors in predicting actual values of a variable with a range of 100 through 110. The Theil's U coefficients calculated from model outputs are presented in Table 6.

---

[2]Theil, p. 32. The analysis and calculations in this section follows the form described in the Michigan State University Department of Agricultural Economics programming unit User's Guide for Program Theil, Version 1.0. The inequality coefficient between predicted and actual value of the variables is considered the most valid for analyzing multiyear forecasts of output coefficients, since all other forms are based upon comparison with actual value in t-1, that is, other statistics are designed for one period projections carried out over several years running with the evaluation of the forecasting ability assuming knowledge of actual happenings in the year or time period immediately previous to that predicted.

Table 6. Theil's U Coefficients

	Basic Run	Complements	Constant VMPs	Constrained
Corn	.056	.088	.034	.016
Wheat	.067	.091	.119	.017
Dry Beans	.054	.065	.108	.011
Soy Beans	.072	.069	.077	.012
Potatoes	.105	.106	.103	.026
Sugar Beets	.025	.026	.022	.019
Hay	.051	.076	.052	.011
Milk	.037	.037	.038	.007
Beef	.080	.080	.080	.017
Hogs	.032	.033	.032	.017
Eggs	.059	.059	.060	.013
Horses	.010	.010	.010	.005
Other	.034	.047	.054	.004

The results of Theil U coefficients analysis and absolute proportional error analysis are not greatly different but comparison of the two values do add insights to the characteristics of the model under the three alternative assumptions when the model is not constrained. It is important to note that the Theil's U coefficient works on the principle of squared errors while the proportional error coefficient use absolute error. The squared error principle causes the magnitude of error to increase the magnitude of the coefficient with an exponential value of two. This type of higher costing of errors of greater magnitude is a fairly common method and seems quite reasonable. Thus it is significant that the basic run has a better percentage margin in tracking ability over the other two unconstrained models using the squared error principle of the Theil's U coefficient than shown by the average absolute proportional error. It is also significant that the potato coefficient looks even worse than in the proportional error analysis. In fact, it has the worst value among all the inequality coefficients in all four model runs.

Evaluation of Model Output

Final output of the model is a result of the action of all of the components of the model. It is very difficult to sort out the sources of inaccuracies in model output. The quantities produced in the 13 enterprises were singled out for performance variables because these are the ones most directly created by the production component. The addition of a production component to the Michigan Model as specified in the theoretical chapter of this thesis required the addition of two ad hoc components to represent input supply and output demand. It also required an exogenous source of technological change and government diversion programs. A much better test of the production component will come after creation of better estimators of these factors which directly affect the production of agricultural commodities. However, many significant conclusions can be drawn at this juncture. The constrained model serves to a significant degree to insert into the production component more accurate values of variables which are otherwise inserted in an ad hoc manner. However, these more accurate values are derived using information which was unknowable at the date for which the model is initialized. In this run, the a's or constant multiplier coefficients for the production functions were inserted as a proxy for technological change and the actual land allocations into crops were inserted to reflect the impact of governmental programs. In fact, the insertion of actual land acreages oversteps the degree to which better information about the impacts of government programs would have aided the performance of the production component. Although it performs quite well in all enterprises, the constrained model still does not accurately reflect the input supply and output demand schedules needed to get exact tracking.

The three unconstrained model runs do not track Michigan's agricultural production as well as the constrained run. They do follow the general trends in production and are good at projecting turning points in production levels. Although the basic run appears to be slightly better than the other two unconstrained runs in tracking ability, the evidence is not conclusive. It shows no superiority in correctly predicting turning points. The ability to follow trends and predict turning points contrasted with average prediction errors of eight to nine percent leads to the conclusion that a major difficulty of the model is the estimation of the magnitudes of the changes. Two factors contributing to this difficulty are inaccurate estimates of year to year technological change and land allocation.

Since the unconstrained runs differ only in their method of allocation crop land, the livestock production quantities are similar in all unconstrained model runs. The most serious correlation coefficient offenders among the livestock categories are the production of milk and the production of eggs. During the 1955-1962 time period there were significant changes in the industrial structure of agriculture. A major change was the shift from diversified farm firms to much more specialized farming, from the weekly allowance of grocery or household money coming from the cream, milk or egg check to production concentrated on very specialized farms. It was the time during which vertical integration in the edible egg industry began. Eggs instead of being sold to local egg stations began to be candled on the farm and transported long distances to centralized markets. It appears that the development of more accurate technology coefficients would greatly improve the performance of the model in these two commodities.

Among the crop activities, the most serious error is the inability to allocate land to the various crops. Therefore, three different land allocation decision rules were used. It appears that among these alternatives the allocation of land through the equating of weighted average VMP (basic run) is best. But implications are that the implicit assumption of homogeneity of land resulting from only one land category being specified among the agricultural inputs was a crucial factor limiting model performance. Further development of the model could certainly profit from more detailed specification of different land inputs.

CHAPTER 7

CONCLUSIONS AND IMPLICATIONS

This study concludes with a summarization of the information gained from the development of the MASS production component, and a discussion of some important areas of research needed to help validate or improve the present production component. Then, some conclusions are drawn from operation of the model. This is followed by a discussion of the practical utility of the model. Next are some brief statements about further modeling which can and should be done on the model to move it into a projection mode so it can be successfully and usefully implemented in planning and decision making. Finally, several sketches are given of alternate directions for model development.

Conclusions and Implications Drawn from the Production Component

The production component was conceived from a desire to permit competition, based on economic criteria, for inputs among the important agricultural commodity activities in Michigan and a feeling that a method better than the commonly used recursive linear programming could be devised. In the production component developed, many of the characteristics of linear programming were maintained but Cobb-Douglas production functions and price-quantity schedules for input supply and output demand were used.

Cobb-Douglas production functions have several characteristics that make them preferable to linear production functions for economists trying to determine optimal input allocation to single production processes. They conform to the principle of decreasing returns to increases in use of individual inputs, if those inputs have exponential coefficients which are less than one and greater than zero. They can have or can be constrained to have increasing, decreasing or constant returns to scale, a characteristic determined by whether the sum of the exponential coefficients is greater than, less than or equal to one, respectively. They can be estimated using the standard statistical tool of regression since they are linear when converted to logrithmic form. When they are estimated statistically, the large body of theoretical knowledge of that field can be used to determine goodness of fit, confidence intervals on the dependent variables, and the accuracy of individual parameters in the function. And they match economists' perception of the relationships between inputs and output well enough to warrant frequent use in production studies.

The price-quantity schedules reflecting input supply and output demand for the agricultural sector of Michigan are composed of connected sloping line segments. Their design grew out of a desire to allow information about elasticities of supply and demand to be used in the model without eliminating the ability to reflect the impacts of salvage and acquisition price differentials. In linear programming, salvage and acquisition prices can be modeled by including additional activities in the tableau; this is not necessary in Cobb-Douglas programming. With the addition of many activities to a linear program the price-quantity schedules as presently used in the MASS model can be approximated, but the additional costs in computer and researcher time usually make such approximations prohibitive. The benefits of the modular construction of the model are evidenced in the flexibility it provides for allowing shifts in supply and demand schedules. For each schedule one point on the schedule is defined in one component of the model, the distribution of the schedule around that point is defined in another component, and the schedule is used in a third component, the production component. A vertical and/or horizontal shift in a particular schedule is effected by entering the change in the component that determines the original point on the schedule. Shifts in elasticity or in the proportional relationship between the original point and the salvage or acquisition price are executed in the component determining the distribution of the schedule around the original point.

In spite of the theoretical advantages, this study did not provide sufficient evidence to conclude that Cobb-Douglas programming is superior to linear programming. Cobb-Douglas programming displayed the same high sensitivity to the specification of price-quantity schedules that linear programming has to its constraints. The first run of the MASS model displayed the significant instabilities often experienced in initial runs of large linear programs. And, similar to experiences with linear programming, repeated parameter adjustments were necessary to bring model performance within an acceptable range determined by previous knowledge about behavior of the system.

The parameter adjustments required to stabilize the tracking ability of the Cobb-Douglas programming procedures highlighted the crucial importance of proper selection of input categories and the interplay between elasticities of supply and demand schedules. If the use of linearly homogeneous Cobb-Douglas production functions is appropriate at the sector level, special care is required in determining the degree to which each input can be transferred from use in the production of each commodity to each of the other commodities and the cost of such transfers. In the production component, the 13 commodity fixed inputs serve to restrain the transfer of other inputs among commodities by forcing decreased returns to increases in allocation of these inputs. In this respect, commodity fixed inputs served as a proxy for the missing structural constraints for such transfers in the component. Since this concept may be difficult to grasp, let us consider a specific case. Consider the use of fertilizer in the production of corn versus soybeans. Corn and soybeans require very different types of fertilizer. Corn requires a significant amount of nitrogen, soybeans require very little, if any. Suppliers of fertilizer are usually prepared to supply sufficient quantities of fertilizer, based on historical trends and their expectations of farmers demands, for both crops. They are not prepared to supply the necessary fertilizer that would be required by a transfer of the total amount of land normally planted to soybeans and corn to all soybeans or all corn. In the production component, fertilizer is represented by one homogeneous input. For the purposes of the model one unit of fertilizer in corn is the same if used for soybeans. Since in the model, corn and beans use the same inputs, except enterprise fixed capital, and the Cobb-Douglas production functions are homogeneous to degree one, the only things keeping a minor increase in expected price of one of these two crops, from causing a complete transfer of the inputs from the other to that crop are the elasticities of demand for the crops and the elasticities of supply of the commodity fixed inputs. Since a portion of the reason that such shifts in production activities do not occur is attributable to fertilizer difference, and the fact that this is not reflected in model structure, commodity fixed inputs serve as a proxy for fertilizer differences in this specific case. There are two major ramifications of this proxy serving characteristic. First, during the construction of the commodity budgets used to establish the exponential coefficients of the Cobb-Douglas functions more attention should have been given to input definition with special attention to inflexibilities built in by supply channels or the previous commitment of an input to a specific production activity. Secondly, regardless of the tracking accuracy of the model we cannot conclude that the elasticities of demand used in the model are accurate. Fine tuning of the model cannot determine these elasticities since the elasticity of supply of commodity fixed capital plays an equally important role in the year to year adjustment determinations.

The process of adjusting the exponential coefficients in the production component and the elasticities of supply and demand used by the component also produced multiplicative coefficients for each year for each commodity (see Appendix A). An increase in the multiplicative coefficient from one year to the next for the production function of a commodity implies that the same quantity for all inputs will produce more output in the second year than in the first. The physical laws of nature make this impossible. In fact, an increase in the multiplicative coefficient results from quality changes in inputs or from increased efficiency in the use of inputs. In this study, as discussed in Chapter 4, the multiplicative coefficients are assumed to reflect changes in technology.

One of the attributes of the Michigan agricultural sector described in Chapter 2 is that there have been significant increases in the productivity of the sector. And one would expect technology as reflected by the multiplicative coefficients in the Cobb-Douglas production functions to increase or at least remain constant over time. Most of the multiplicative coefficients determined in the Calculation routine (see Appendix A, Table A-5) are close to or larger than their predecessors. But there are some exceptions that deserve mention in this chapter. The largest percentage decrease in one year is in the multiplicative coefficient for potatoes in 1960. Two other commodities, soybeans and beef, show a decreasing trend in the later years of the time simulated after increases in the first few years. All three of these commodities were among those with poor tracking records in the empirical tests for accuracy recorded in Chapter 6, and were the three worst offenders in the analysis using Theil's U. These significant decreases in multiplicative coefficients are contrary to logic and their existence has not been rationalized.

The three unconstrained model runs assume the multiplicative coefficient for each commodity increases linearly with time. The multiplicative coefficients estimated by the Calculation routine for milk and eggs, in addition to those for soybeans and beef mentioned in the preceding paragraph, appear to violate this assumption to a degree that causes a negative correlation between actual Michigan production of these two commodities and their simulated production levels in the basic model run. The multiplicative coefficients calculated during the development of the production component used information that was not available in 1955, the linearity assumption was an attempt to put a constraint on the use of this information. The rationale for the linearity assumption was that researchers in 1955 would have fairly accurate ideas about technological change trends through 1962, but that they would probably not have accurate knowledge about year to year changes. It is safe to conclude that a technological change component constructed for use with this model, used for making projections, should not be constrained to this linearity assumption.

While the production component parameters were being adjusted the Cobb-Douglas programming algorithm, which is central to the production component since it solves the complex set of simultaneous equations, often diverged instead of converging. In other words, it often iterated away from the solution instead of moving toward it. This problem necessitated repeated changes to the algorithm. The final version, described in Chapter 5, demonstrated an ability to find a solution over a fairly wide range of parameter changes, but its computational efficiency is not held up as an example for nonlinear operations research. The efficiency of the algorithm can probably be significantly increased by the application of appropriate knowledge. Although the 35 seconds of central processor time required by the model is not large, by the standards of most simulation models, the production component algorithm accounts for more than half of the time used.

The main conclusion to be drawn from the production component, given its assumptions, is that the levels of production of Michigan's agricultural commodities are highly dependent on the relationship between input and output prices and advances in technology. This sensitivity is greater than was perceived at the beginning of this study and has implications on the research needed in conjunction with further uses of this component as part of the KASS model.

Production Component Engendered Research Needs

There are several important areas of research needed to help validate and improve the production component. This discussion will begin with those which have the most radical impact on the production component and move to those that will have a more qualitative impact on the component and will be of value only if the research discussed first does not invalidate the structure of the component. The discussion begins with research on the applicability of Cobb-Douglas production functions, moves to research on the defining of input and output categories. Then production decisions are explored, followed by needed price determinations. Finally, parametric impacts of changes in industrial structure and technological change projections conclude the discussion.

The production component is a representation of activity at an aggregate state level. It is very legitimate to ask whether or not Cobb-Douglas production functions are appropriate to use at the state level. This functional form is very commonly used in research at the farm level. But Cobb-Douglas production functions are obviously not mathematically additive. It is also true that the marginal productivity of inputs vary widely on the individual productive units within the state. Analysis of these arguments indicate that they are also applicable to the farm level. Although most farms are divided into separate fields, each having different characteristics, Cobb-Douglas production functions are estimated for the aggregate farm. Even within fields the marginal productivity of inputs vary widely. Research on the applicability of Cobb-Douglas production functions cannot be based on these arguments. It may be possible to look at goodness of fit of data on the input-output quantities at the state level and compare these to similar information at the farm level to determine whether or not the functional form assumption is as applicable, in relative terms, at the two levels.

The production component includes 13 enterprises and 24 inputs. The enterprises were defined on the basis of commodities produced. The criteria used to select the specific commodities was their present or future importance as income generators for the sector. The experience gained during this study brought these design specifications into serious question. Most of the Michigan cost of production data available is Telfarm data, which is based on farm types. It may be more relevant to model Michigan's agricultural sector by defining enterprises using these farm types. Since most livestock farms, especially beef and dairy, also produce much of their own feed, it may be better to include the crop production inputs in the livestock enterprises. Cash grain farms usually produce several commodities to spread out peak work loads; it may be appropriate to structure the model accordingly. A descriptive research project, analyzing the structure of the agricultural sector, the degree to which commodities compete with or complement each other and the interdependency among production decisions would enhance further development of the production component. Seasonal labor requirements do have an impact on production decisions that is not directly included in the present production component. This is a result of the inputs in the component being selected and grouped according to their asset fixity. Although the 13 inputs defined as commodity fixed inputs serve to constrain the transfer of otherwise homogeneously defined inputs, such as fertilizer, as discussed in the previous section, the recommended research could provide guidelines for including input categories of more relevance to users of model projections and more relevant to production decisions.

The production component allocates resources in three steps. First, it simultaneously allocates land to crop activities; then, it determines commodity-fixed capital for the livestock production; finally, it simultaneously solves for the remaining input quantities. Research on the timing and impact of production decisions would determine the validity of this allocation process. Production decisions are definitely not simultaneous. For annual crops the major determination of input quantities can probably be estimated using an annual model. It is less certain in livestock activities, since each livestock activity has a different production cycle length and adjustments in production levels occur throughout the year.

The complex process of deciding how much to produce has been simplified in the production component by assuming profit maximization, subject to within year static constraints. The assumption is probably valid. Assuming it is, the problem becomes one of determining how those making production decisions attach a cost to each input and how they perceive the value of those inputs at the time they are allocated. Because this information was not available, the parameters of the production component were derived by adjusting their original estimated values based on model performance. This process crudely follows the technique of regression estimation. And in simulation models, as in regression, if a sufficient number of parameters are estimated and their values are not constrained, perfect tracking of historical events will result. But, more than a perfect tracking is desired in structural simulation--a realistic modeling of the behavioral and physical characteristics of the Michigan agricultural sector is also a goal. Research on the effective prices of agricultural goods and services would help determine the validity of the production component. And, if the present structure of the component is maintained, the parameters which determine prices in the model should be estimated for an annual effective level; in other words, in a manner which would reflect production decision-makers' allocation behavior using once-per-year informational inputs. Since agricultural economists have always been involved in studying farm management, an extensive literature review would probably provide valuable inputs to this suggested research.

The agricultural sector is in the process of significant structural transformation. During the time modeled, 1955 through 1962 and up to the present, farms have been increasing in size and becoming more specialized. This has had important impacts on the response of the agricultural sector to price changes and on the relationships among commodities and their inputs. Research is recommended which would estimate the impact of the past changes in the industrial structure of Michigan's agriculture and project the expected impacts of several widely diverging, but realistically possible, scenarios of its future structure. This research would provide a basis for some very worthwhile impact analysis work using the MASS model.

Finally, research is recommended to estimate time paths of sector-level Cobb-Douglas production functions for Michigan's agricultural activities using Project 80&5 results as a guide. The Delphi study of that project provides some very interesting information, which, if quantified and used in model projections could provide inputs to the research allocation decisions of the MSU College of Agriculture and Natural Resources.

The research recommended in this section covers a very wide range. Each topic recommended is a research slice cutting across a separate characteristic of all the production activities of Michigan's agricultural sector. They were selected to show the broad range of research activities that can contribute to the production component. The scope of an individual study could be reduced to include a single commodity and still contribute to the development of the production component; but the conceptual framework of such a study must recognize that the individual commodity is a part of the total sector, rather than an isolated event.

Conclusions Drawn from Model Runs

There is very little data collected on the quantity of inputs used in the production of Michigan's important agricultural commodities. Livestock populations and crop acreage are the only commodity-specific time series statistics reported for inputs. Of these, only dairy population and crop acreages are directly included as inputs in the MASS model. Crop acreages, as estimated by the unconstrained runs of the model, tended to miss actual acreages planted by about the same proportion in each year as the projections of total production of these crops missed actual production. This does not lead necessarily to the conclusion that accurate estimations of acreage allocations would correct all the tracking errors of the model, but it would improve model tracking. The fact that the two estimates err in the same approximate proportions probably indicates that all input categories need to be adjusted by this same proportion, since the production functions have constant returns to scale. Some conclusions about the realism of the dynamics of the model can be portrayed by a heuristic description of the impacts of acreage allocations.

Let us consider a hypothetical case with the actual production and land allocation of a specific crop being ten percent higher than model outputs for a particular year. For this crop, let the elasticity of production or exponential coefficient for land be .20. Next, assume an exogenously inserted ten-percent increase in the land allocated to that crop to correct the land allocation error. The direct impact of this input adjustment is an increase in production by the ten-percent increase in land times its production elasticity (.20), or an increase of two percent. Holding the commodity price and quantities of the other inputs constant, the value marginal products of all other inputs are increased by this same two percent. Allowing the model to proceed with its normal adjustment of the input quantities, except for the exogenously entered land quantity, while holding the prices of all inputs and the commodity fixed, will result in a ten percent increase in the quantity of each input. This occurs because the assumption of fixed input prices causes the least cost combination of inputs to be in fixed proportions to each other, proportions which would be the same as in the original solution. And the combination of constant returns to scale and fixed commodity price cause the determination of a unique solution to hinge on the fixed land input. Thus, the ten-percent increase in land would result in a ten-percent increase in all other inputs and therefore the quantity of output. Assumption of fixed prices is equivalent to assuming infinite price elasticity of supply and demand. The crucial dynamics of the model are in the impacts of relaxing these elasticity assumptions. Relaxing the assumption of infinite price elasticity of demand for the crop will result in the model changing all input quantities, still excepting the fixed land quantity by the same proportion. The proportional adjustment is dependent on the price elasticity used in the model. A highly elastic demand schedule will result in a proportional increase slightly less than ten percent, unitary elasticity will result in zero change from the original solution; and an inelastic schedule will cause a proportional decrease. Since the demand curves in the model all have price elasticities greater than three, let us consider the elastic case in conjunction with the relaxing of fixed input prices. Decreasing the price elasticity of supply of any input will have a twofold impact on each of the other flexible inputs. Since the reduction of its elasticity causes the quantity of the input to adjust less than, but in the same direction that it otherwise would; and we have ascertained that the present adjustment is an increase, the direct impact on output quantity would be in the negative direction, and commodity price would increase. The elastic crop demand schedule causes the price impact to be less than that of quantity. And the net of the two impacts is that inputs shift in the same direction. A reduced adjustment in one input causes reduced adjustments in the remaining inputs.

The complexity of the hypothetical case increases significantly with an expansion to more than one commodity. The impacts of the change in the allocation of land to one crop can be traced to all input and output quantities in the model. The original change requires adjustments in the allocation of land to each of the other crops, and the resulting adjustments to inputs common to both crops and livestock create changes in the livestock commodities. The dynamics of the model as traced in the case of one commodity provide sufficient basis to conclude that price elasticities and price shifts used in the model impact input and commodities in the general direction expected for adjustments in the modeled sector. It can also be concluded that inputs reflect the same general characteristics of complementarity without eliminating the ability to have some substitutability through changes in the proportional relationships among inputs. However, this study did not quantitatively validate these dynamic relationships.

The case example demonstrated that an adjustment which would only eliminate the errors in the land allocation process would not completely eliminate the errors in projecting production quantities. This provides the basis for conjecturing that the errors in both land allocation and production quantities are the result of some common causal factors. The dairy population as modeled also misses actual levels by approximately the same proportion as modeled milk production misses actual production. Although the error is a small percent of actual quantities, the negative correlation between actual and projected values is disconcerting. It appears that the problem would increase with an extension of the model run to 15 years.

From the model runs we can conclude that although the model, as presented here, needs further work, it can, even in its present form, provide important contributions.

Practical Utility of the Model

A simulation run of the present model, starting from 1970 and provided with price and weather forecasts through 1985, can provide important contributions to three broad aspects of Michigan's planning and policy-making processes: understanding the socio-economic system, formulating agricultural policies, and focusing research activities. These aspects are somewhat overlapping; for example, both research and an increased understanding of agricultural problems certainly contribute to policy formulations.

Understanding Michigan's Agricultural Sector

Detailed analyses of the behavior of the model under a range of data and parameter assumptions and policy assumptions provide a comprehensive view of the complex and dynamic socio-economic system called Michigan's agricultural sector. This, combined with the identification of causal and structural relationships required by the model-building process itself, can contribute significantly to an improved understanding of, and sharpened perceptions regarding, the factors influencing agriculture in general, as well as Michigan's agriculture in particular. This was demonstrated in Chapter 6, where model runs with differing land allocation assumptions contributed to an understanding of the allocation process, and the consequences of the different allocation procedures highlighted the complex interactions of the sector.

To the degree that the simulation model faithfully represents the relevant behavioral patterns of the reality being simulated, this heightened understanding can be a valuable asset in reducing some of the uncertainty farmers, agri-businessmen, and policy-makers necessarily face.

Policy-Making

A more direct input to the policy-making process is the capability of the model to explore the consequences and implications of a wide range of agricultural policy options. By impacting the model inputs to simulate the influence of policy options, the model can project time paths of relevant output variables under alternative and conceivably very complex combinations of policies. Thus, using the same data available and used for more traditional (e.g., Project 80&5) type of projections, the model can take into account many more complex policies and alternative future scenarios than can be done by hand or with a desk calculator. In this way, a good deal of the uncertainty concerning the agricultural sector's response to various economic and policy environments can be reduced.

Two examples of the model's ability to address policy issues can be drawn from those presented in Chapter 2. The first is the expressed concern about the availability of land for agricultural use within Michigan. Many land use policies are presently being discussed. Usually, tax concessions for agricultural lands, zoning laws, subdivision regulation and recreational land purchases are discussed individually. In reality, all of these are concurrent and interactively influence the future of agriculture in the state. Through adjustments in the quantity and prices of agricultural land, impact analysis of various mixes of these policies can be executed using multiple runs of the model. Resulting model outputs will indicate the effects on individual commodity production in addition to gross and net farm income.

Secondly, the model could be used to address environmental issues. Pollution abatement regulations are going to have increasing impacts on both livestock and crop production. The order and timing of implementing regulations may have a large impact on the competitive advantage of individual enterprises within Michigan. In the longer run the method of achieving pollution abatement will affect the mix of agricultural production. The model can aid the analysis of the policy options through the comparison of model outputs resulting from estimates of policy impacts on enterprise budgets and technology coefficients.

Focusing Research

A third practical contribution the model can make to Michigan's agricultural planning and policy making is as a focus for research activities. There are primarily three ways in which use of the model can provide a central theme to coordinate and guide research. First, indications of the relative sensitivity of model behavior to the values of data and parameters used in the model gained during model development or by running the model with different values of these variables will suggest research priorities to improve the available estimates of the most important data and parameter inputs of the model. In some cases, new information gathering and parameter estimation methods may have to be devised to accomplish the task. For example, the experiences of developing the production component indicate that model behavior is more sensitive to price-quantity schedule shapes and locations than thought at the beginning of this research, therefore more effort should have been spent in determining these parameters. State level parameters for these schedules are difficult to estimate and new techniques may have to be found to estimate them.

Another area of research which the model's application will motivate is investigations into structural relationships among and the behavior of the component parts of the agricultural sector. These efforts will be necessary to continually improve and keep up to date the model's assumptions and representations of the sector and to keep it relevant to the needs and concerns of production planners and policy makers in a changing world. An example of a structural relationship needing work in the model is the link between the profitability of dairy and dairy cow population. As indicated in the conclusions in a previous section of this chapter, the present modeling of dairy population is only very weakly connected to dairy profitability, and improvements in model structure are appropriate.

Finally, technological research may be suggested by alternative model runs which speculate on the likely consequences of the introduction of various innovations which may not actually be developed presently, such as hybrid wheat, induced twinning of beef cows or a cloning process of reproduction in chickens. The speculations of the Delphi study of Project 80&5 are particularly appropriate subject matter for this. Of course, the projected consequences would have to take into account projections of the expenses of such research and development.

In summary, a simulation model such as has been presented here can be a useful and valuable tool in the reducing of uncertainty in the production planning and policy making processes of the state. It can provide a comprehensive view of the complex dynamic agricultural sector while at the same time facilitating policy impact analysis and providing guidelines for agricultural research efforts.

Model Implementation

Derivation of most of the practical utility benefits discussed in the preceding sections are predicated by the need to use the model in a projection mode. The model was initialized for 1955 primarily for validation as a tracker of history, to provide an understanding of the system modeled and to guide research on data and parameter estimation and structural identification. However, the 1955 through 1962 restriction of model runs in this study limit these benefits. Although the present model can be used for projection runs, this is not recommended because many variables which should be generated internally must be entered from exogenous sources.

A more user-oriented approach requiring modification of the model would reduce the complexity of making projection runs and contribute to the general acceptability of the model. It is recommended that the model be first purged of the information inputs to it that were not available in 1955, with the exception of national price levels. Primarily, this is technological change parameter, weather factors, and expected commodity prices. Next, the model still simulating from 1955 should be modified to generate these values either year by year during the model run or based on parameters derived from 1955 expectations. Then a model run for 1955 through 1970 or 1975 could be used for model improvement and validation. After these steps, the model, changed to simulate from 1970 and used for projection runs, would have a much more relevant test and a more integrated structure. The initialization of projection runs for 1970 is recommended because Project 80&5 and the Michigan Model provide much of the necessary data. Although this recommendation for future development of the model has a large initial development cost, it would lower the cost of making alternative projection runs and increase the derivable benefits. After the model is moved into the projection mode, it will be necessary to modify it to keep it current with changes in Michigan's agricultural sector and the continual changes in research needs.

One of the significant advantages of the modeling work already completed and described in these pages is a result of its modular construction. This allows separate pieces or several parts to be used with additional modeling work in a broad spectrum of applications. The remaining sections of this chapter illustrate only a few of the possibilities.

Alternative Model Formulations

The form of a simulation model should be determined by the purpose of the research the model is designed to aid. In this section are several worthwhile research projects that would profit from the use of the modeling work described in this study. First the possible contribution to commodity specific research is discussed. Then, two options for updating Project 80&5 are presented. A trend projection model facilitating the use of secondary data as it is released and the current opinions of agricultural experts concludes this section.

Suppose a researcher wishes to estimate the impacts of a specific change in technology or governmental regulation affecting the dairy industry. Since the dairy industry competes with other agricultural activities for agricultural resources, the impact of changes to the dairy industry includes impacts on the rest of agriculture. If these impacts are significant the researcher could use the parts of the MASS model which link to the dairy industry. Since the number of people in Michigan is not affected greatly by the dairy industry, the information from the population component resulting from a base projection run could be simplified to reduce computational costs. Thus, the research could concentrate on developing a detailed model of the dairy industry, plug this into the relevant pieces of the MASS model as adapted for the needs of the specific research, and get results which are procedurally documented and could be easily repeated with assumption changes reflecting alternative possible impacts.

The Michigan agricultural sector modeling work described in this study facilitates two options for updating Project 80&5. The first option would use a model of Michigan's agricultural sector that would draw heavily from the Michigan Model. Since the Michigan Model is largely a computerization of Project 80&5, this option would use the same conceptual framework as Project 80&5. The only difference would be that the computer would be used to reduce the pencil and paper calculations. Under this option the first projections made by the steering committee would be loaded into the computer and each subcommittee would be asked to evaluate and adjust the projections relevant to their respective areas of responsibilities. With the use of an interactive teletypewriter terminal, the modifications made by the subcommittees would be entered into the model at subcommittee meetings, and the impacts of the changes would be immediately available. Inconsistencies would be quickly discernable, and the subcommittee could respond accordingly. This would reduce some of the delays inherent in a non-computerized approach. There would also be a reduction in the effort necessary to pull together the results of the work of the subcommittees, since this information is all fed to one location.

The second option is to use a Cobb-Douglas-based production function concept, with interrelated competition for inputs as formulated in the MASS model. In this option, the steering committee would still provide an initial projection which the subcommittees would adjust. However, the use of the MASS model would require considerable effort to educate subcommittee members about Cobb-Douglas programming sufficient for making cogent changes directly to its parameters. Thus, this second option is not recommended. It should be possible, however, to implement the first option and ask for additional information that would provide the basis for the development of a Cobb-Douglas model within the Agricultural Economics Department.

If it were desirable to release five, ten, and 15 year projections of Michigan's agriculture on a regular basis, the development of a trend projection model could be worthwhile. Such a model could be formulated by adding a regression capability to the Michigan Model which would be used to determine trend lines for crop acreages, livestock numbers, input use and commodity yield parameter estimates. The impacts of expected future developments on these parameters would be entered into the model and the results of model runs would provide the basis for the five, ten and fifteen year projections. This trend projection model would allow the projections to be constantly updated. The sophistication of the method of inserting the impact of expected events can be increased greatly by including many feasible events and the probability and timing of their occurrance. Then a most likely projection with a confidence interval around the projected values can be derived from model runs.

In summary, the results of this study provide a broad base of information and model structure usable for a wide variety of further research. The model structures created can be used for modeling agricultural sectors of regions other than Michigan and for improving existing projections of Michigan's agriculture. The data used and parameters estimated are available in machine readable form for use in research projects involving Michigan's agriculture whether it is to improve the MASS model or to develop alternative information which will help production planning or policy makers.

REFERENCES

REFERENCES

Brandow, G. E. Interrelationships Among Demands for Farm Products and Implication for Control of Market Supply. Bulletin 680. University Park: The Pennsylvania State University Agricultural Experiment Station, August, 1961.

deHaen, Hartwig. "Systems Models to Simulate Structural Change in Agriculture." European Review of Agricultural Economics. 1(4).

Dillon, John L. The Analysis of Response in Crop and Livestock Production. Oxford: Pergammon Press, 1968.

Ferris, John N. Files Department of Agricultural Economics Letter from Ernest Girbach, President of Michigan Agricultural Conference, October, 1953.

________. Memorandum to Steering Committee, Project 80&5. Informal Minutes of Steering Committee of April 16, 1971, dated May 17, 1971.

________. Personal Communication. October, 1975.

Forester, Jay W. World Dynamics. Cambridge, Massachusetts: Wright-Allen Press, 1971.

Hamilton, H. R., et al. Systems Simulation for Regional Analysis: An Application to River-Basin Planning. Cambridge, Massachusetts: M.I.T. Press, March, 1969.

Hathaway, Dale E. Government and Agriculture. New York: The Macmilland Company, 1963.

Heady, Earl O., C. B. Baker, Howard G. Diesslin, Earl Kehrbert and Sydned Staniforth. Agricultural Supply Functions. Ames, Iowa: Iowa State University Press, 1961.

Heck, Gene W. Building Rural Michigan: A New Era In Agrarian Industrial Enterprise. House Republican Caucus Rural Development Task Force. Lansing, Michigan: Republican Office, House of Representatives, State Capitol, 1974.

Johnson, Glenn L., Albert N. Halter, Harald R. Jensen and D. Woods Thomas. Managerial Processes of Midwestern Farmers. Ames, Iowa: The Iowa State University Press, 1961.

Johnson, Glenn L. and C. Leroy Quance, Eds. The Overproduction Trap in U.S. Agriculture. Baltimore: The John Hopkins University Press, 1972.

Kearl, C. D. and Darwin P. Snyder. "Farm Cost Accounts." Ithaca, New York: Cornell University Agricultural Experiment Station, 1960-1973.

Kost, William E. "Weather Indexes: 1950-1963." Quarterly Bulletin. Vol. 47, No. 1. East Lansing: Michigan Agricultural Experiment Station, Michigan State University, August, 1964.

Lerohl, Milburn L. "Expected Prices for U.S. Agricultural Commodities, 1917-62." Ph.D. dissertation, Michigan State University, August, 1965.

Madden, J. Patrick and Earl J. Partenheimer. "Evidence of Economies and Diseconomies of Farm Size." Size, Structure and Future of Farms. Edited by A. Gordon Ball and Earl O. Heady. Ames, Iowa: Iowa State University Press, 1972.

Manetsch, Thomas J., et al. A Generalized Simulation Approach to Agricultural Sector Analysis: With Special Reference to Nigeria. East Lansing: Michigan State University, November, 1971.

Manetsch, Thomas J. and Gerald L. Park. Systems Analysis and Simulation with Applications to Economics and Social Systems Part I and Part II. East Lansing, Michigan: Michigan State University Press, 1974, Chapter 11.

Michigan Agricultural Experiment Station. "Project Outline, Michigan Agricultural Sector Study (MASS)." Project 3169. East Lansing: Michigan State University, February, 1975.

________. Research Reports 37-52, and 180-194. East Lansing: Michigan State University, 1966-1973.

Michigan Crop Reporting Service. Michigan Agricultural Statistics. Lansing, Michigan, 1975.

Michigan Department of Agriculture. "Michigan Agricultural Land Requirements: A Projection to 2000 A.D." Lansing, Michigan, February, 1973.

Michigan Governor's Office. "Farmland and Open Space Preservation Act." (HB4244) Approved by Governor May 23, 1974, Act. No. 116. Public Acts of 1974.

________. "Governor's Special Commission on Land Use Report." January 5, 1972 (mimeo).

Michigan Department of Natural Resources Land Use Office. Michigan's Future Was Today's .... Lansing, Michigan: Allied Printing, 1974.

Petit, Michel Jean. "Econometric Analysis of the Feed-Grain Livestock Economy." Unpublished Ph.D. dissertation, Michigan State University, 1974.

Quance, C. Leroy. "Farm Capital: Use, MVPs, Capital Gains or Losses." Unpublished Ph.D. dissertation, Michigan State University, 1967.

Richardson, Harry W. Regional Economics. New York, New York: Praeger Publishers, 1972.

Rossmiller, George E. Farm Real Estate Value Patterns in the United States 1930-1962. Agricultural Economics Report No. 31. East Lansing, Michigan: Department of Agricultural Economics, Michigan State University, 1972.

Rossmiller, George E., et al. Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985. East Lansing: Michigan State University, 1972.

Theil, H. Economics Forecasts and Policy. Amsterdam: North Holland Publishing Company, 1965.

Trimble, Richard L., Larry J. Connor and John R. Brake. "Michigan Farm Management Handbook--1971." Agricultural Economics Report No. 191. East Lansing, Michigan: Michigan State University, May, 1971.

U.S. Department of Agriculture. Farm Income State Estimates 1949-73. FIS 224 Supplement. September 1974. pp. 63-64.

Watt, David L. "Michigan Model." A collection of papers prepared for the Policy Advisory Board of the Computer Library for Agricultural Systems Simulation. East Lansing: Michigan State University, May, 1974.

Wolf, Chris, Thomas J. Manetsch and Claudia Winer. "A FORTRAN Executive Program for Continuous Flow Simulation Models--SIMEX 1." Training Program Paper. East Lansing: Michigan State University, 1974.

APPENDICES

APPENDIX A

DERIVATION OF DATA AND PARAMETERS USED
IN THE MODEL AND THEIR VALUES

The transition from the Michigan Model to the MASS model caused many changes in the data and parameter needs of the model. Some of the changes resulted from the change to 1955 as the initial year modeled. The remainder were required by the new production component. The final model requires values for over 1500 variables to make an eight-year simulation run. Values of some of the variables changed during the process of reinitializing the model for 1955 and all of the added data and parameters required by the new production component are presented in this appendix. First, the data and parameters for human and dairy cow populations are presented. These are followed with the prices required by the production component. Then the derivation and values of the production function parameters complete the description in this appendix.

Human Population

The initial (1955) farm and nonfarm populations were derived from an interpolation between the 1950 and 1960 censuses of population for all age cohorts except the 0-4 year and the 80+ categories. The interpolation was based on the following reasoning. Individuals 0-4 years old in 1950 were 5-9 years old by 1955 and 10-14 years old in 1960.

Assuming fairly constant death and migration rates for the population over the ten-year period 1950-1960, the number of individuals in a particular age group should be approximately halfway between the population one age cohort younger in 1950 and one age cohort older in 1960. Thus the interpolation was made by taking the average of the two relevant groups for each five-year age cohort in the range 5-80 years of age. The 1955 population for the 0-4 year old age group was approximated by dividing the 5-9 year old population by the 10-14 year old population, both as recorded in the 1960 census, then multiplying the result by the 5-9 year old population as approximated for 1955. This method assumes that the proportional relationship between two adjacent cohorts is stable enough over a five-year period to be an accurate method of approximating this cohort. The same principle was exercised in estimating the remaining cohort populations. The initial population used in the model is presented in Table A-1. Birth, death and migration rates used in the MASS model are the same as in the Michigan Model.

Dairy Cow Population

The initial populations for dairy cattle cohorts (POPDC) are 365,000 for 0-1 year olds, 412,000 for 2-4 year olds and 365,643 for cows over 4 years old. The two older cohort populations initialized were estimates of the distribution of the 777,643 dairy cows reported on Michigan farms October-November 1954 in the United States Census of Agriculture. The number in youngest cohort resulted from normal replacement numbers approximated by several model runs. Fertility, death and cull rates were the same as in the Michigan Model.

Table A-1

Initial Human Population

	Farm (POPF)		Nonfarm (POPNF)	
Age Cohorts	Female	Male	Female	Male
0-1	5548	5902	83236	87504
1-4	22191	23610	332946	350019
5-9	28706	31324	355122	369410
10-14	27116	30032	283257	283606
15-19	20708	23449	235556	225518
20-24	17426	20028	231551	221771
25-29	13506	15468	262672	252934
30-34	16362	15761	278584	268149
35-39	17824	17808	257924	247945
40-44	17774	19894	234246	233803
45-49	16223	17894	204062	208426
50-54	14978	17033	180880	190627
55-59	14289	16397	156940	164584
60-64	13538	15851	137042	143408
65-69	10756	13694	107180	109902
70-74	8294	11001	84674	79823
75-79	5152	7563	58036	51505
80-84	5340	6757	57049	46354
85+	1013	1087	11087	7616

Commodity Prices

Actual and expected prices for corn, wheat, soybeans, potatoes, milk, beef, hogs, and eggs were drawn from Lerohl.[1] Actual prices received for dry beans, sugar beets, hay and horses came from Michigan Agricultural Statistics 1956-1963. The remaining expected prices were entered ad hoc. Prices used in the model are presented in Table A-2.

Input Prices

As explained in the text, each input price was the result of an input price index times a base price. Price indices used were U.S. farm cost indices which most closely corresponded to the input categories in the model. Base prices were established by finding the quantity that produced a reasonable per unit cost for each input for 1955 when multiplied by the 1955 index for that input. Base prices and price indices for all inputs are shown in Table A-3.

Production Function Parameters

The published statistics of Michigan's agriculture do not include the statistics necessary to estimate a production function for each commodity represented in the production component if the estimation process is constrained to standard regression techniques. This problem was overcome by estimating a budget for each enterprise and using two assumptions also used in the production component. These two assumptions were: (1) Cobb-Douglas production functions that are homogeneous to degree one satisfactorily represent the production relationship for each enterprise and, (2) producers maximize profits by allocating

[1]Lerohl, pp. 105-131.

Table A-2

Actual (APRP) and Expected (AEPY) Price Series

Commodity		1955	1956	1957	1958	1959	1960	1961	1962
Corn	Expected	1.35	1.27	1.22	1.11	1.05	1.03	1.05	1.10
	Actual	1.35	1.29	1.11	1.12	1.05	1.00	1.08	1.10
Wheat	Expected	2.15	1.87	2.00	1.97	1.75	1.70	1.70	1.95
	Actual	1.99	1.97	1.93	1.75	1.76	1.75	1.79	1.95
Dry Beans	Expected	6.90	6.90	6.90	6.90	6.90	6.90	6.90	6.90
	Actual	6.90	6.50	7.50	6.50	5.60	5.50	6.50	6.30
Soybeans	Expected	2.10	2.15	2.13	2.03	2.05	1.94	2.20	2.22
	Actual	2.22	2.18	2.07	2.00	1.96	2.13	2.28	2.34
Potatoes	Expected	2.13	2.00	1.91	1.82	1.66	2.05	1.55	1.65
	Actual	1.77	2.02	1.90	1.31	2.27	1.85	1.47	1.55
Sugar Beets	Expected	12.10	12.10	12.10	12.10	12.10	12.10	12.10	12.10
	Actual	11.50	12.40	11.40	11.50	8.70	12.20	10.50	11.50
Hay	Expected	20.40	20.40	20.40	20.40	20.40	20.40	20.40	20.40
	Actual	20.40	19.90	18.80	19.80	18.40	17.50	19.20	21.50
Milk	Expected	3.93	4.05	4.20	4.20	4.10	4.17	4.20	4.18
	Actual	4.05	4.21	4.24	4.13	4.19	4.21	4.22	4.23
Beef	Expected	16.00	15.25	15.50	18.47	22.68	20.50	19.50	21.00
	Actual	15.60	14.90	17.20	21.90	22.60	20.40	20.20	21.30
Hogs	Expected	19.50	15.62	15.62	17.50	15.75	14.62	15.38	16.00
	Actual	15.00	14.40	17.80	19.60	14.10	15.30	16.60	17.80
Eggs	Expected	37.00	36.00	38.50	38.80	36.70	35.00	33.90	32.00
	Actual	39.50	39.30	35.90	38.50	31.40	36.00	35.50	35.55
Horses	Expected	516.00	516.00	533.00	555.00	560.00	565.00	571.00	582.00
	Actual	516.00	516.00	533.00	555.00	560.00	565.00	571.00	582.00
Other	Expected	1.00	1.00	1.01	1.04	0.98	0.99	0.99	0.99
	Actual	1.00	1.00	1.01	1.04	0.98	0.99	0.99	0.99

Table A-3

Base Price (BPRINP) and Annual Price

Index (APRINP) for All Inputs

Input	Base Price	PRICE INDEX 1955	1956	1957	1958	1959	1960	1961	1962
Fertilizer	.0416	1.02	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Dairy Cows	10.00	1.20	1.30	1.30	1.40	1.50	1.60	1.60	1.50
Durable Capital	10.00	.94	.94	.97	1.01	1.02	1.03	1.04	1.06
Expendable Capital	1.00	.99	.99	1.00	1.00	1.00	1.00	1.01	1.01
Corn	.0221	1.06	1.03	1.01	.99	1.00	.98	.98	1.00
Hay	.01	1.02	.99	.94	.99	.92	.87	.96	1.07
Protein Feeds	.0275	.96	.86	.97	1.02	1.01	1.10	1.60	1.30
Tractors	2.00	.94	.94	.97	1.01	1.02	1.03	1.04	1.06
Combine Picker	9.00	.94	.94	.97	1.01	1.02	1.03	1.04	1.06
Labor	1.78	.89	.92	.96	.99	1.05	1.09	1.10	1.14
Enterprise Fixed Capital	1.00	.94	.94	.97	1.01	1.02	1.03	1.04	1.06
Land	150.00	.91	.96	1.07	1.13	1.25	1.29	1.31	1.35

inputs in a manner that equate the price of inputs with the value marginal products expected from their allocation. The first assumption can be written as follows:

$$Y = a \prod_{i=1}^{n} X_i^{b_i} \text{ with } \sum_{i=1}^{n} b_i = 1.0$$

where:

Y is the quantity of output produced

a is a constant, in this description it is referred to as the multiplicative coefficient

X_i is the quantity of the i^{th} input used in the production process

b_i is a constant exponential coefficient having a specific value for each value of i

i is an integer 1, 2, 3, ..., n.

The second assumption implies:

$$VMP_i = \frac{b_i Y P_y}{X_i} = Px_i$$

where:

VMP_i is the value marginal product of the i^{th} input

P_y is the price of the output expected at the time production decisions are made

Px_i is the price of the i^{th} input.

The equation implied by the second assumption can be reformulated into:

$$b_i = \frac{X_i Px_i}{Y P_y}$$

Since,

$$\sum_{i=1}^{n} b_i = 1.0$$

is assumed. It follows that,

$$\sum_{i=1}^{n} X_i Px_i = YP_y$$

With these two assumptions the exponential coefficients are equal to the proportion of total production cost attributed to their respective inputs.

The exponential coefficients were calculated from budgets for each enterprise. The budgets evolved from a compromise among diverse sources of information that were often inconsistent. A computer program, which will be described later, was written to make several of the consistency checks. Since this program also calculated the constant coefficients, it is called the Calculation routine.

The first budgets for corn, wheat, hay, and milk came from the farm cost accounts from Cornell.[2] The costs recorded for the years 1959 through 1972 were aggregated, as near as possible, into the input categories defined in this study. The average of the proportion of total cost attributed to each input was calculated using the same weight for each year. Budgets for the remaining enterprises were constructed from cost of production information from several sources.[3]

The Calculation routine is a simple Michigan agricultural production model designed for a simulation run from 1955 through 1962. The exogenous inputs are: (1) linear time trends in yield per acre (head)

---

[2]C. D. Kearl and Darwin P. Snyder, "Farm Cost Accounts," Ithaca, New York: Cornell University Agricultural Experiment Station, 1960-1973.

[3]The major sources of information were the published reports of Projects 80 and 80&5, the 1973 through 1975 publications of Telfarm, a mail in computerized records service for Michigan farmers located at Michigan State University, and "Michigan Farm Management Handbook-1971" by Richard L. Trimble, Larry J. Connor, and John R. Brake, East Lansing, Michigan: Agricultural Economics Report No. 191, May 1971.

of each crop (livestock), (2) actual acres (number) of each crop (livestock), (3) expected price per unit of output of each commodity, (4) price per unit of each input, and (5) exponential coefficient of each input used in the production of each commodity as described above.

For each year of the model run, the Calculation routine determines both the quantity of each input required, and the multiplicative coefficient needed for the Cobb-Douglas production function of each commodity.

The computational process is derived from the equations presented earlier in this section. The technical detail of the calculation is not included in this discussion because although there are several alternatives, all will give the same results.

The first consistency check made possible by the calculation routine was to determine if the quantity of each input used in each production process was reasonable. The second was to see if trends in input use in each production process was reasonable. The third was to check the totals of the inputs used in the agricultural sector were reasonable. Finally, the trends in these totals were observed.

The inconsistencies found were analyzed and to the degree that their sources could be traced, alternations in commodity budgets were made. The final exponential coefficients resulting from this iterative process (see Table A-4) are used in the production component of the MASS model.

After the final exponential coefficients were determined, the multiplicative coefficients from the calculations routine (Table A-5) were regressed for a linear time trend. The regression was set up with time (T) from 1954 in years as the independent variable and the multiplicative coefficient (AA) was the dependent variable. The intercept (AI) and slope (AS) coefficients estimated from the regression of each time-series of multiplicative coefficients are included at the bottom of Table A-5. These two variables (AI and AS) are used in the production component of the MASS model to calculate the "a" value used for each commodity in each year.

Table A-4

Production Function Exponential Coefficients (b's)

Input Commodity	Fertilizer	Dairy Cows	Durable Capital	Expendable Capital	Corn	Hay	Protein Feeds	Tractor	Combines Pickers	Labor	Enterprise Fixed Capital	Land
Corn	.1832	.0	.0495	.1188	.0	.0	.0	.1349	.2257	.0037	.1165	.1677
Wheat	.1803	.0	.1015	.1324	.0	.0	.0	.1396	.1271	.0336	.1100	.1755
Dry Beans	.1170	.0	.0705	.1159	.0	.0	.0	.1790	.1861	.0559	.1311	.1445
Soybeans	.1270	.0	.0400	.1300	.0	.0	.0	.1333	.1826	.0475	.1180	.2216
Potatoes	.1520	.0	.1198	.0573	.0	.0	.0	.1375	.0	.2967	.1999	.0368
Sugar Beets	.1390	.0	.1368	.0390	.0	.0	.0	.1015	.0	.3399	.1848	.0590
Hay	.1145	.0	.0706	.0797	.0	.0	.0	.1794	.0	.0903	.1645	.3010
Milk	.0	.0450	.0550	.0500	.1445	.1945	.0464	.0156	.0	.3085	.1405	.0
Beef	.0	.0	.0700	.0600	.2500	.1752	.0663	.0027	.0	.1703	.2055	.0
Hogs	.0	.0	.0200	.0500	.5093	.0	.1670	.0152	.0	.1014	.1371	.0
Eggs	.0	.0	.0100	.0700	.1996	.0	.1773	.0033	.0	.3694	.1704	.0
Horses	.0	.0	.1900	.0500	.1052	.1635	.0868	.0248	.0	.1486	.2311	.0
Other	.0500	.0	.0590	.0385	.0097	.0118	.0042	.0677	.0506	.1251	.1717	.4117

Table A-5

Cobb-Douglas Multiplicative Coefficients (AA) from the

Calculation Routine and the Parameters Derived from a Linear Time Trend Regression

	Corn	Wheat	Dry Beans	Soybeans	Potatoes	Sugar Beets	Hay	Milk	Beef	Hogs	Eggs	Horses	Other
1955	9.082	6.093	2.361	7.625	3.325	.630	.630	.506	.052	.0189	.038	.0052	16.795
1956	9.635	6.865	2.395	7.524	3.577	.638	.638	.491	.062	.0210	.039	.0052	17.724
1957	10.199	6.620	2.465	7.720	3.834	.654	.654	.478	.069	.0239	.038	.0050	17.776
1958	11.295	7.161	2.535	8.158	4.105	.669	.668	.490	.070	.0226	.039	.0050	18.516
1959	12.028	7.633	2.592	8.208	4.603	.687	.683	.505	.067	.0228	.041	.0049	19.512
1960	12.396	7.903	2.639	8.660	3.824	.699	.695	.499	.058	.0252	.044	.0049	19.559
1961	12.345	7.971	2.676	7.914	5.047	.705	.704	.509	.054	.0257	.046	.0050	20.877
1962	12.070	7.212	2.730	7.959	4.842	.719	.717	.534	.056	.0254	.051	.0051	21.443
Intercept parameter *(AI)	8.894	6.235	2.304	7.588	3.157	.616	.616	.48145	.0636	.0192	.0342	.0052	16.238
Slope parameter (AS)	.497	.210	.0544	.0852	.220	.0132	.0128	.0044	-.00057	.00087	-.00174	-.00002	.618

* Value for 1954 (in the regression 1955 = 1)

APPENDIX B

ACTUAL AND MODEL PROJECTED OUTPUTS

Graphs and tables of actual and modeled production of the 13-sector performance variables are presented below. The 13 graphs are presented first, then the 13 tables. Both carry the same information, only the form of conveyance is different. Each graph and each table presents the actual production and the model results from four model runs. Each table has five columns of model output. The first, labeled actual, lists actual production in Michigan as recorded in Michigan Agricultural Statistics for the years 1955 through 1962, or, in the case of horses is an estimate of Michigan horse population. The information listed in the first column for the commodity "other" is the index numbers of farm output for the Great Lakes States.[1]

The remaining four columns list model output results for the basic run, land allocation assuming complementarity, land allocation assuming constant value marginal products of land within crops, and the constrained model run, respectively. These model runs are described in Chapter 6. The graphs use the following symbols to represent actual and model run results.

---

[1]USDA, Changes in Farm Production and Efficiency: A Summary Report 1966. Statistical Bulletin No. 233 (Washington, D.C.) Revised June 1966, p. 15.

◇ actual performance of the sector

□ basic run

○ land allocation assuming perfect complementarity

△ land allocation assuming constant VMPs within crops

✳ constrained run

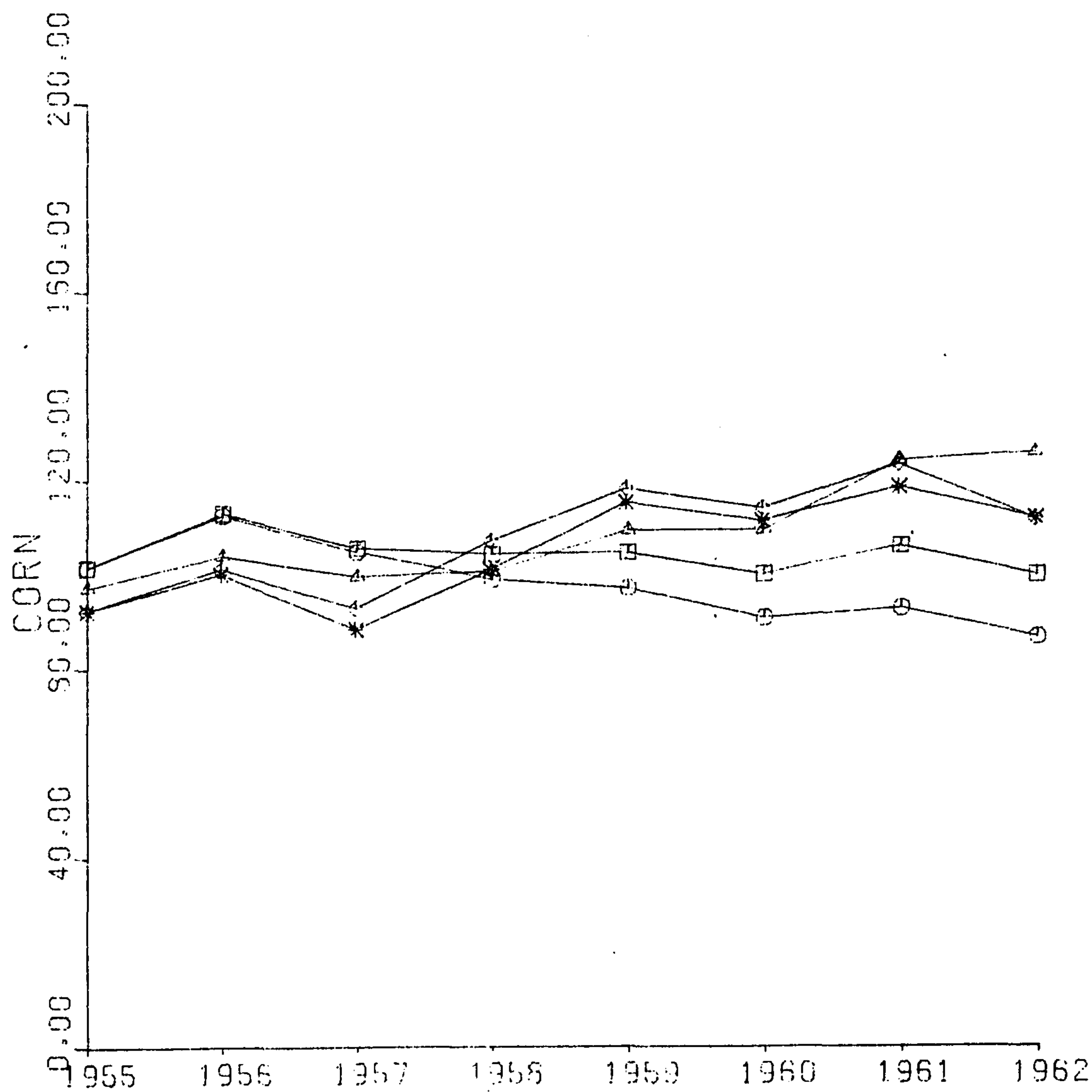

Figure B-1. Model output.

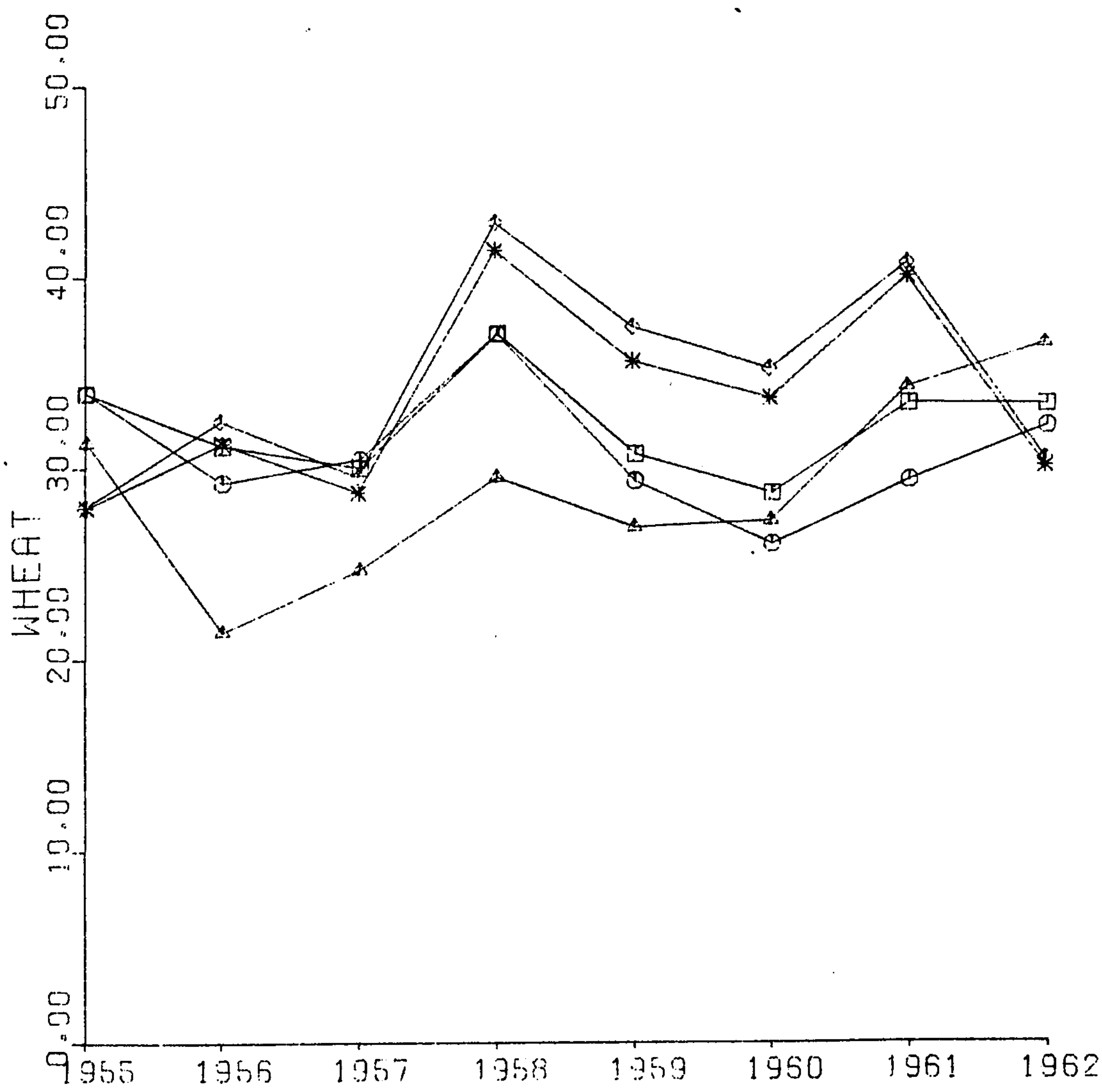

Figure B-2. Model output.

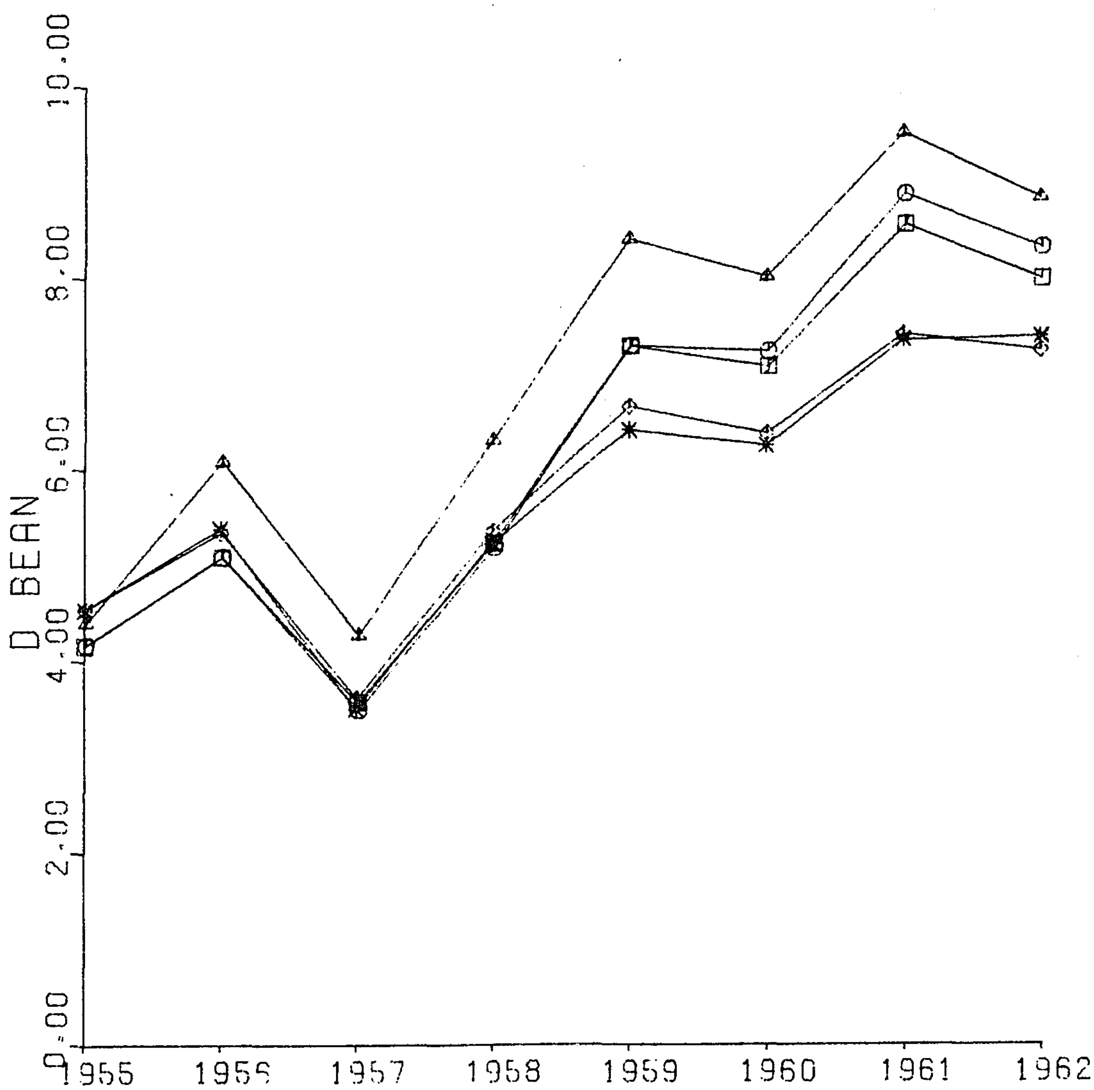

Figure B-3. Model output.

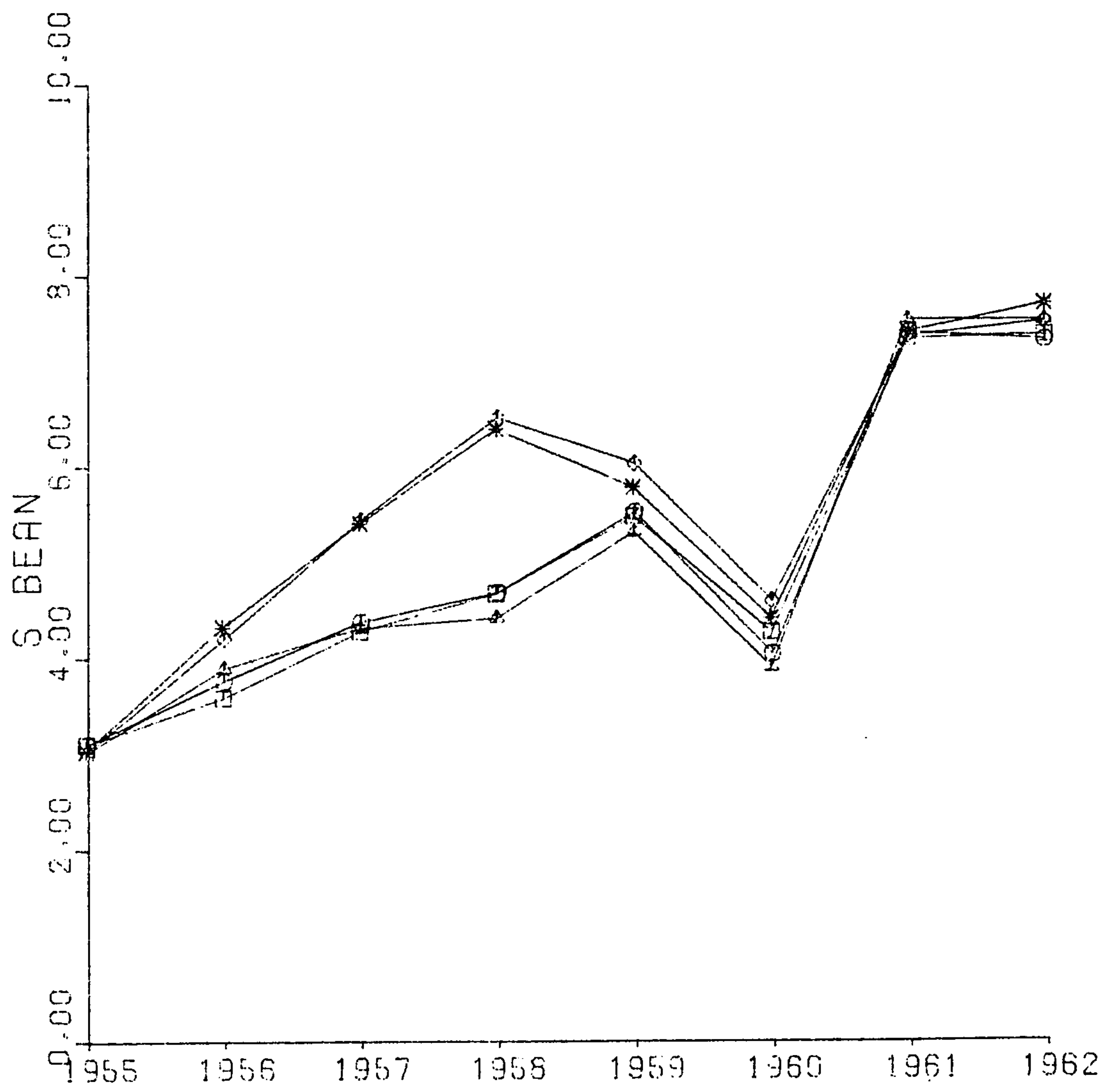

Figure B-4. Model output.

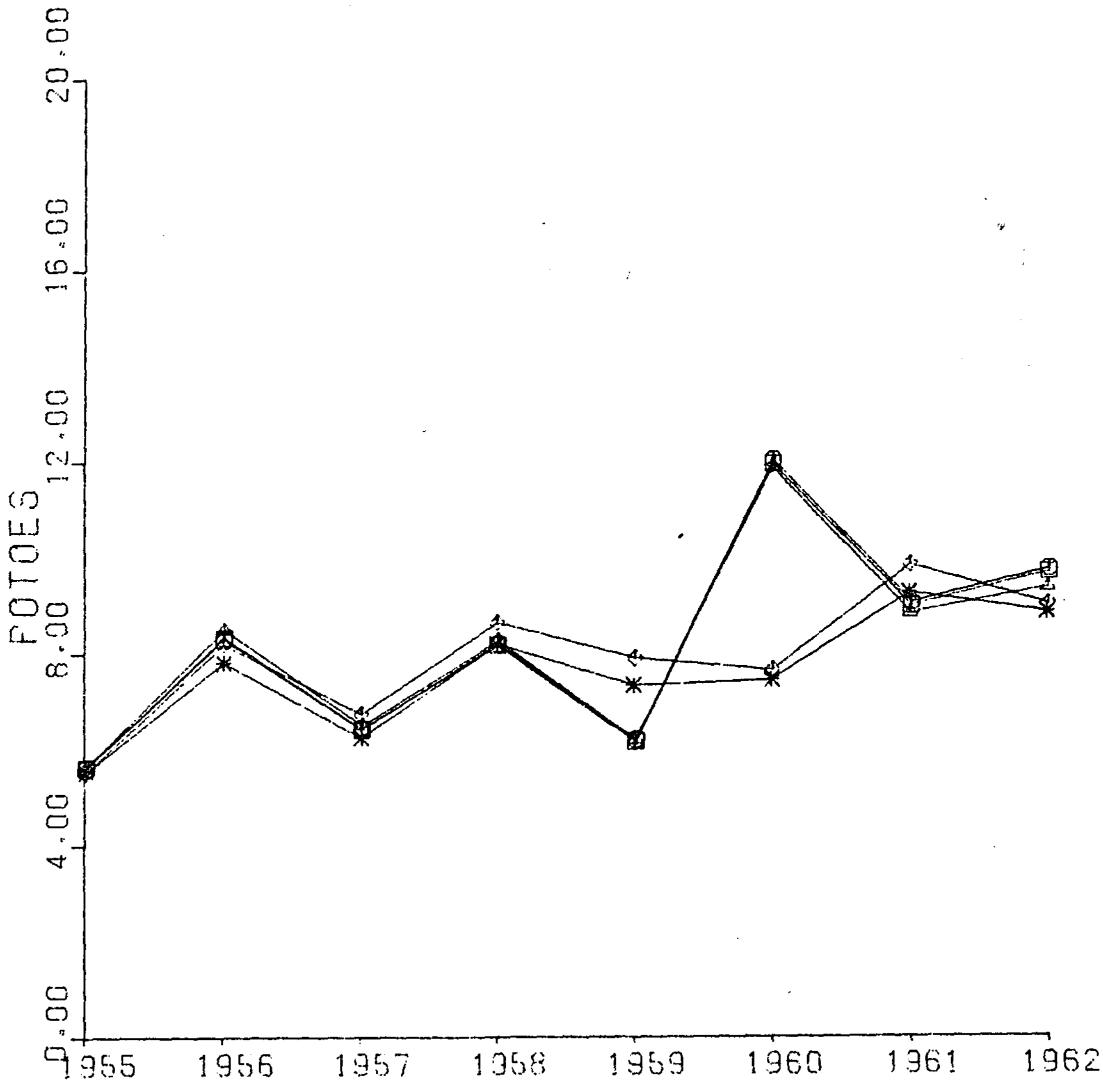

Figure B-5. Model output.

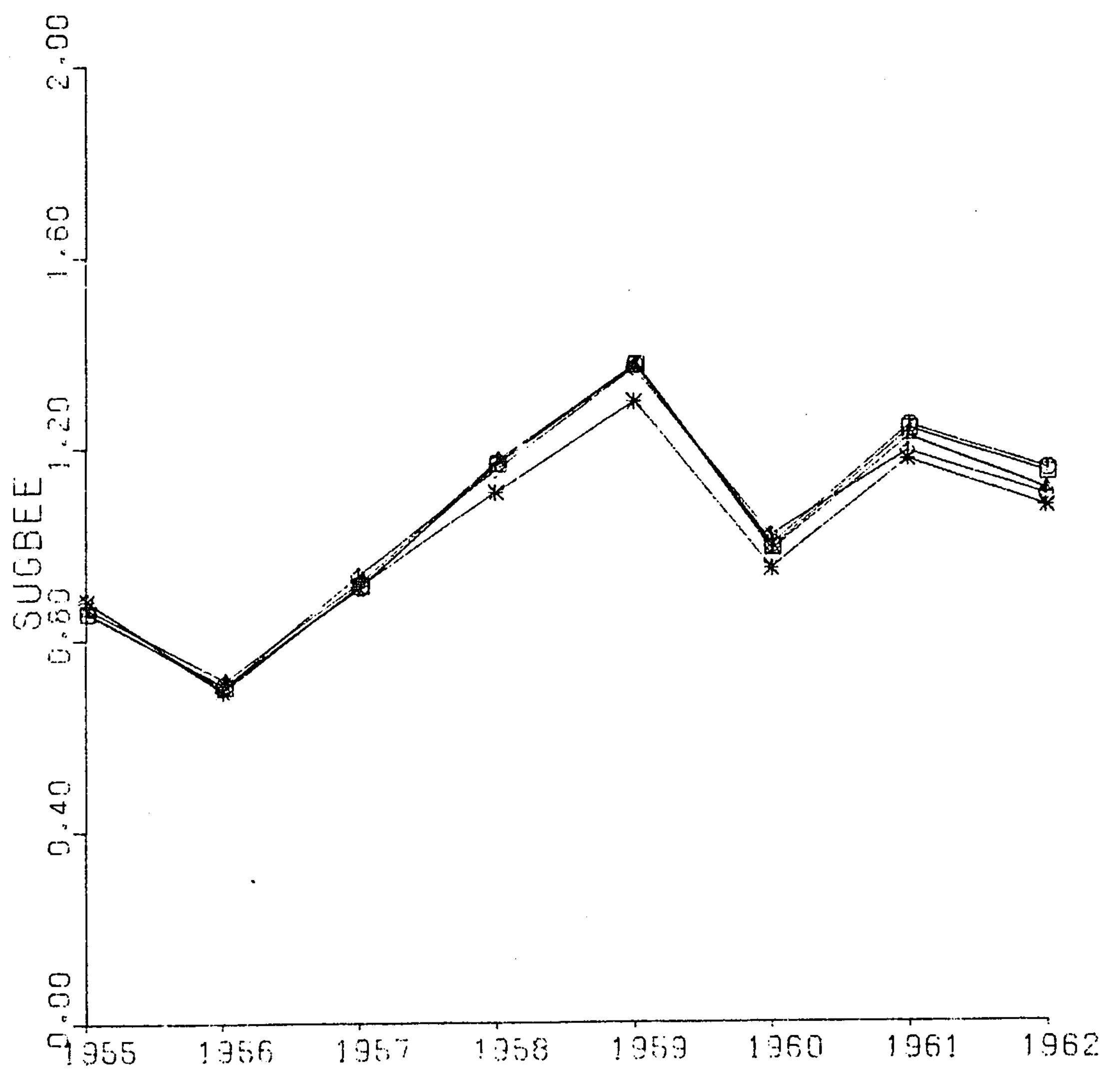

Figure B-6. Model output.

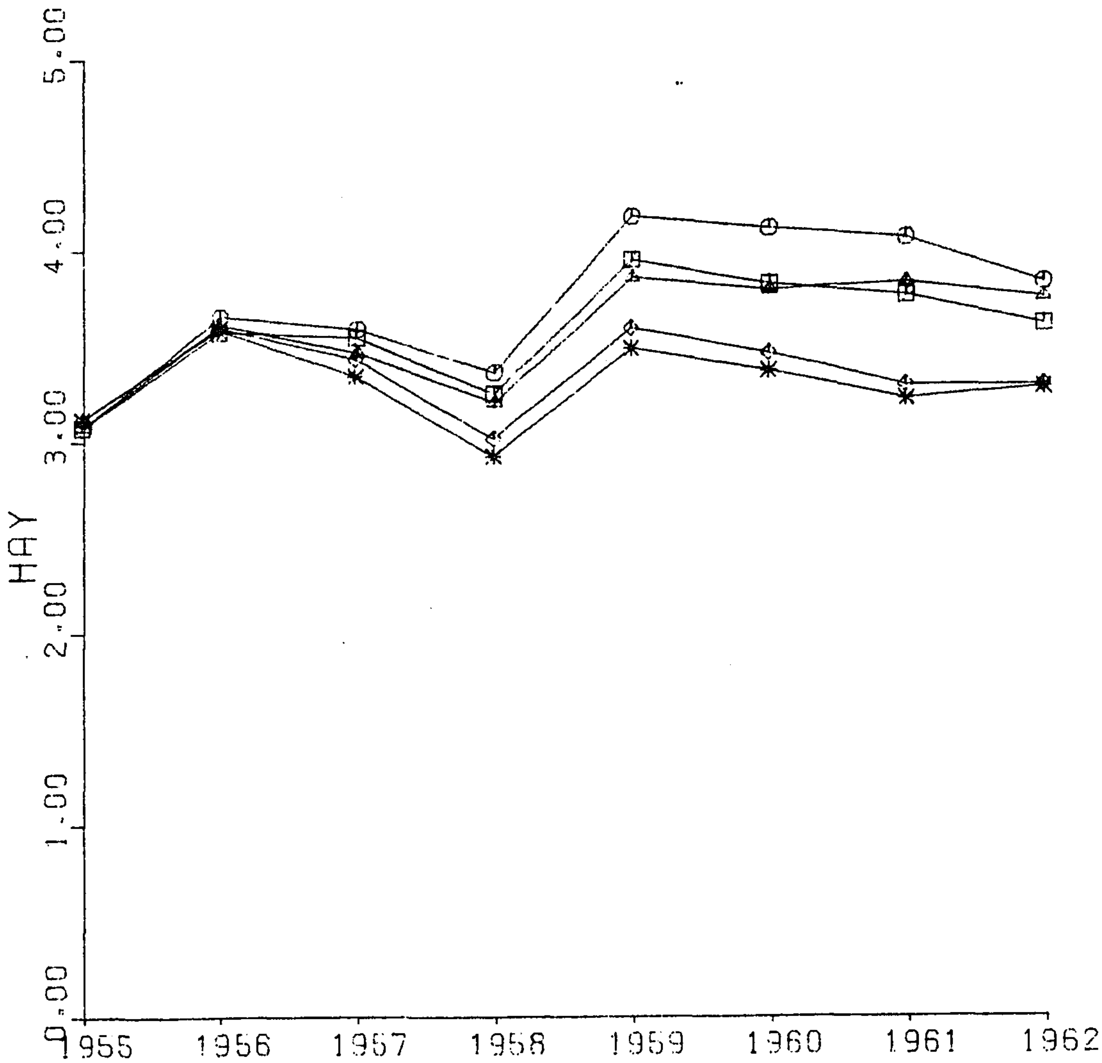

Figure B-7. Model output.

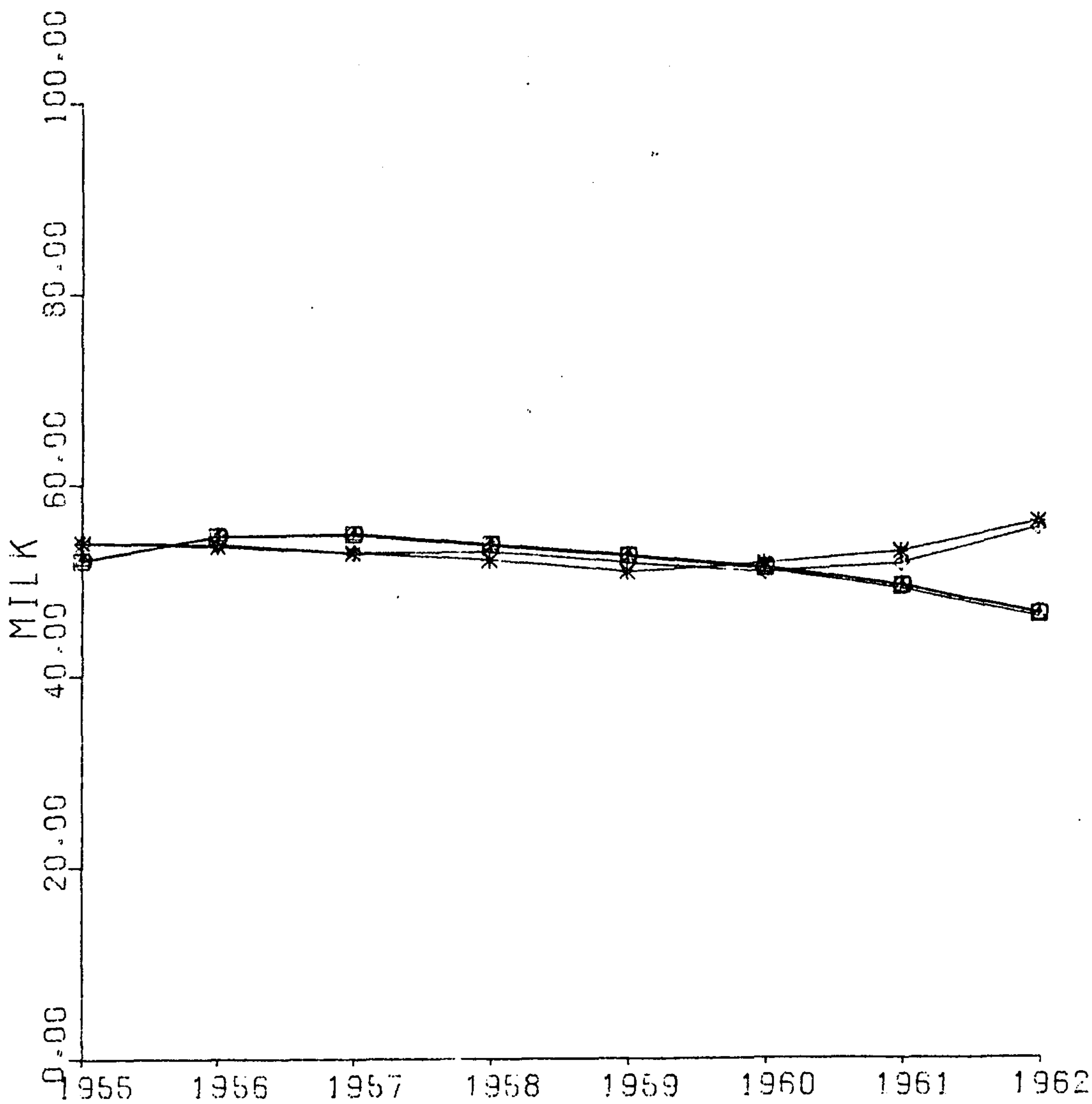

Figure B-8. Model output.

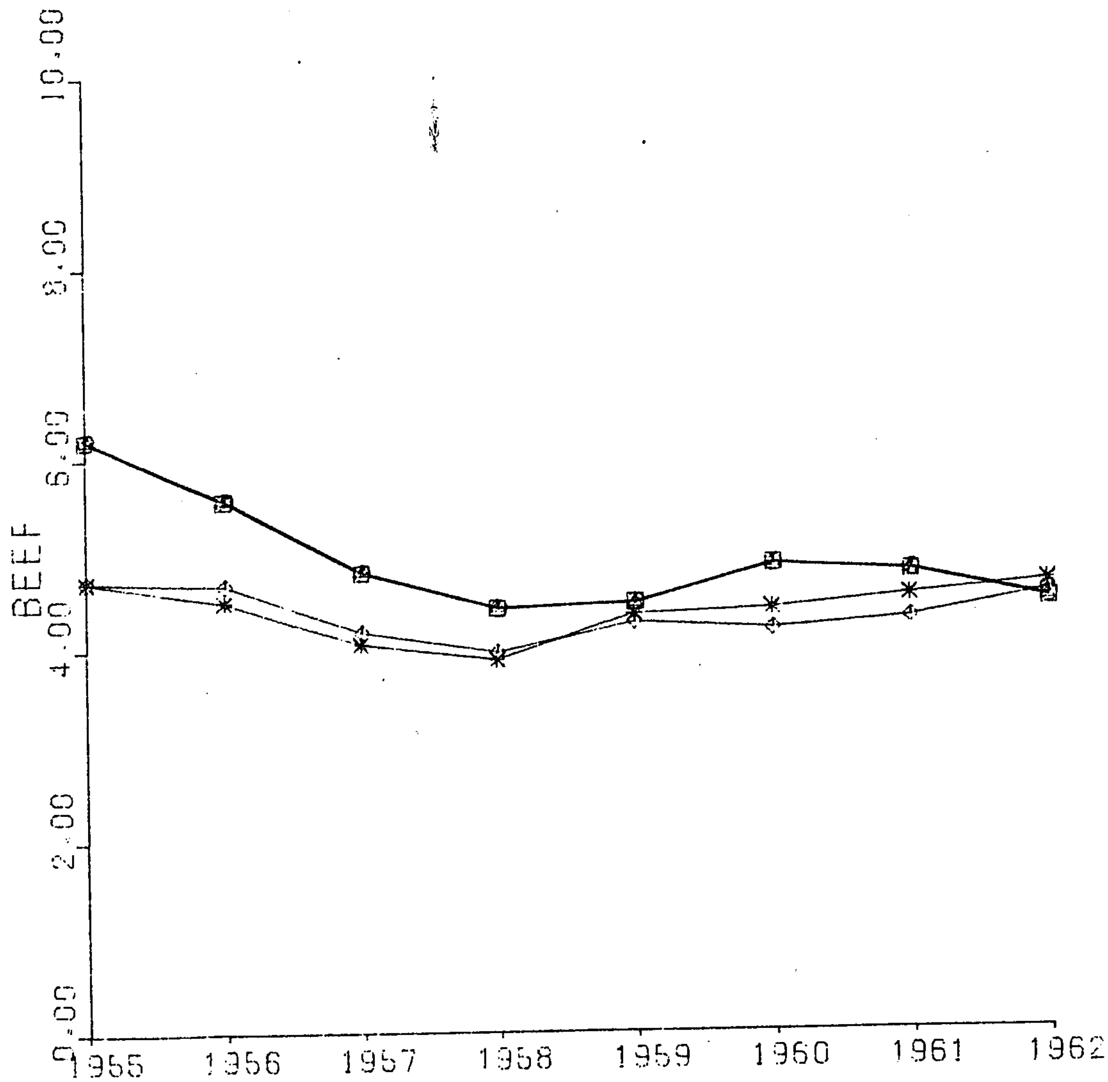

Figure B-9. Model output.

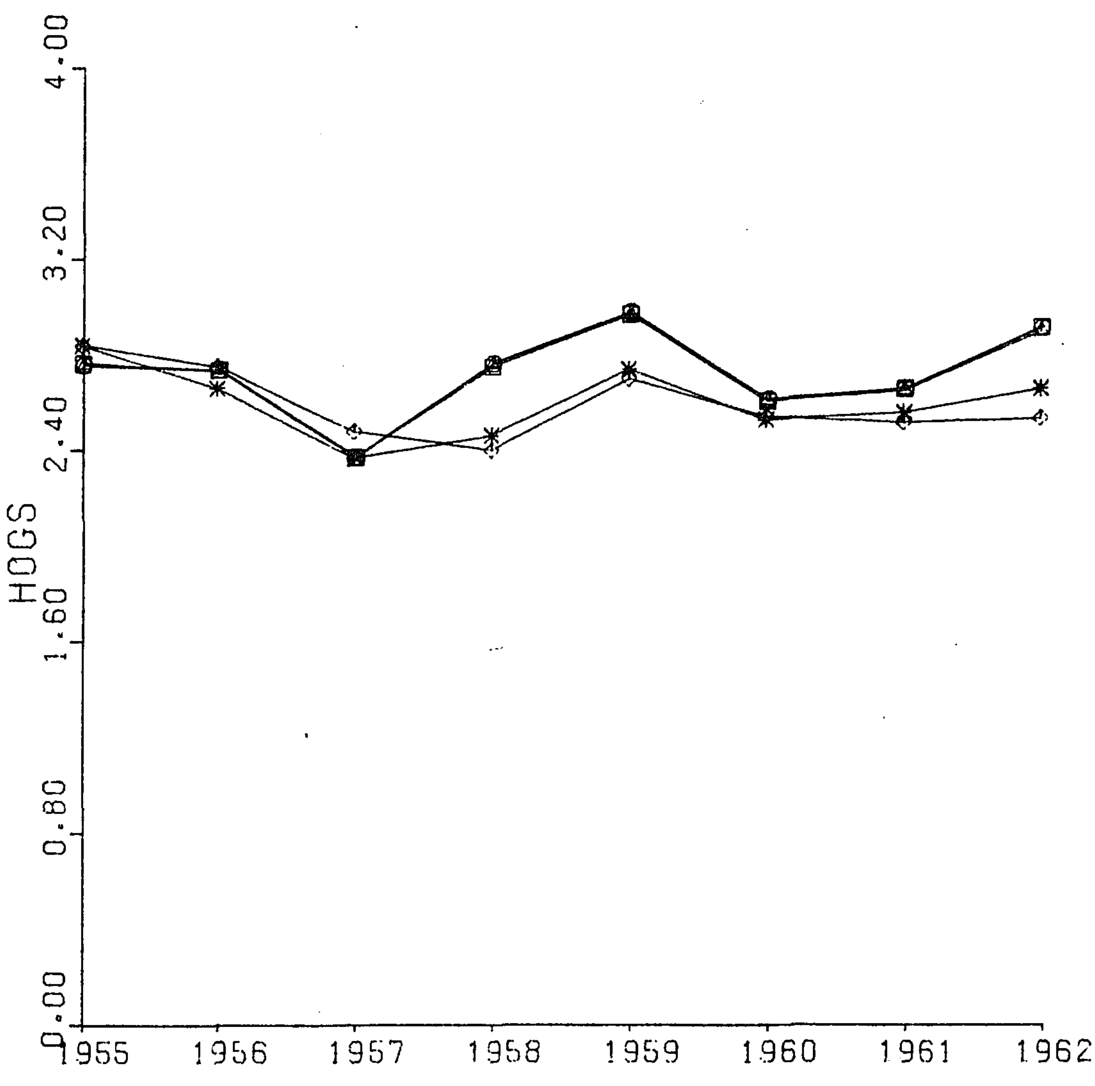

Figure B-10. Model output.

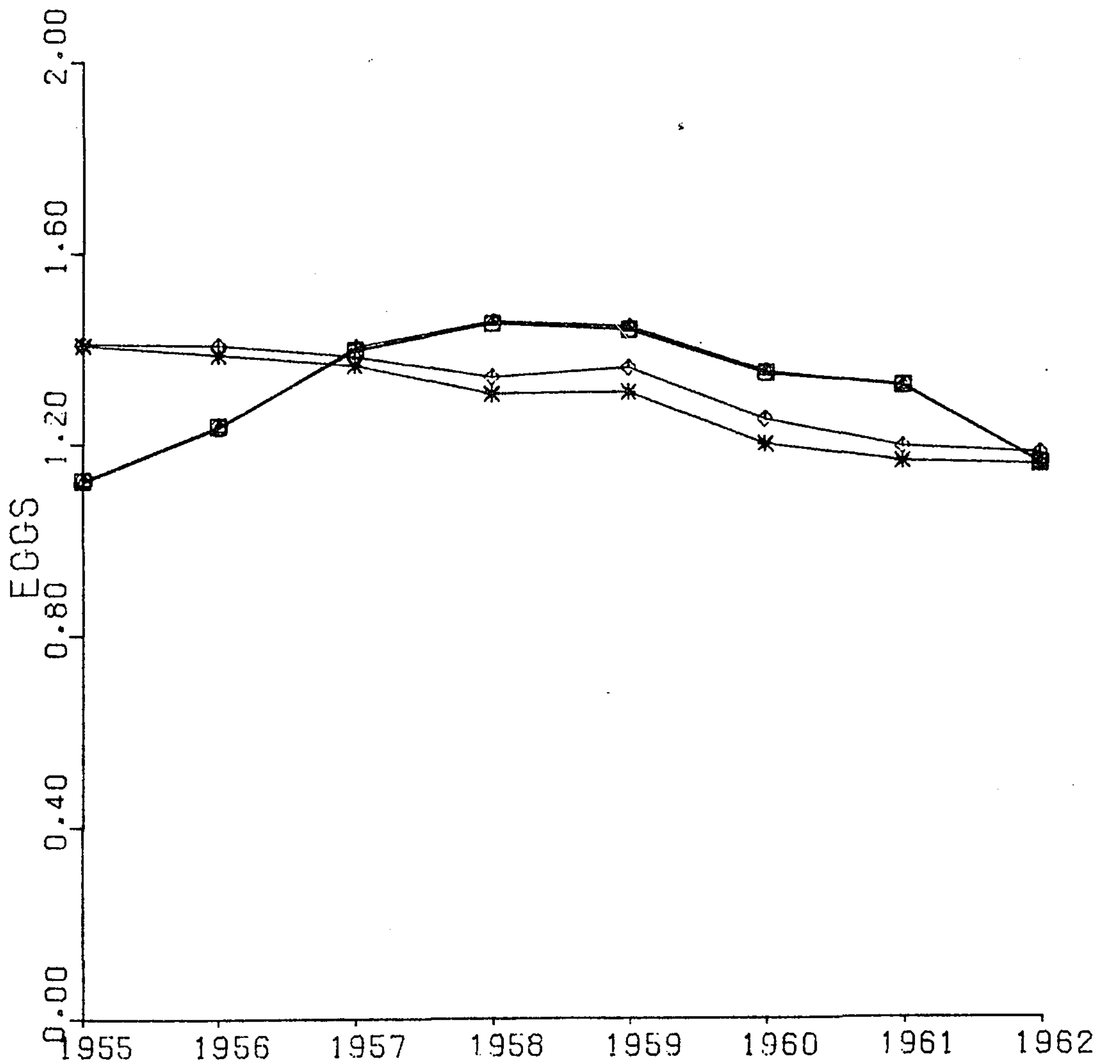

Figure B-11. Model output.

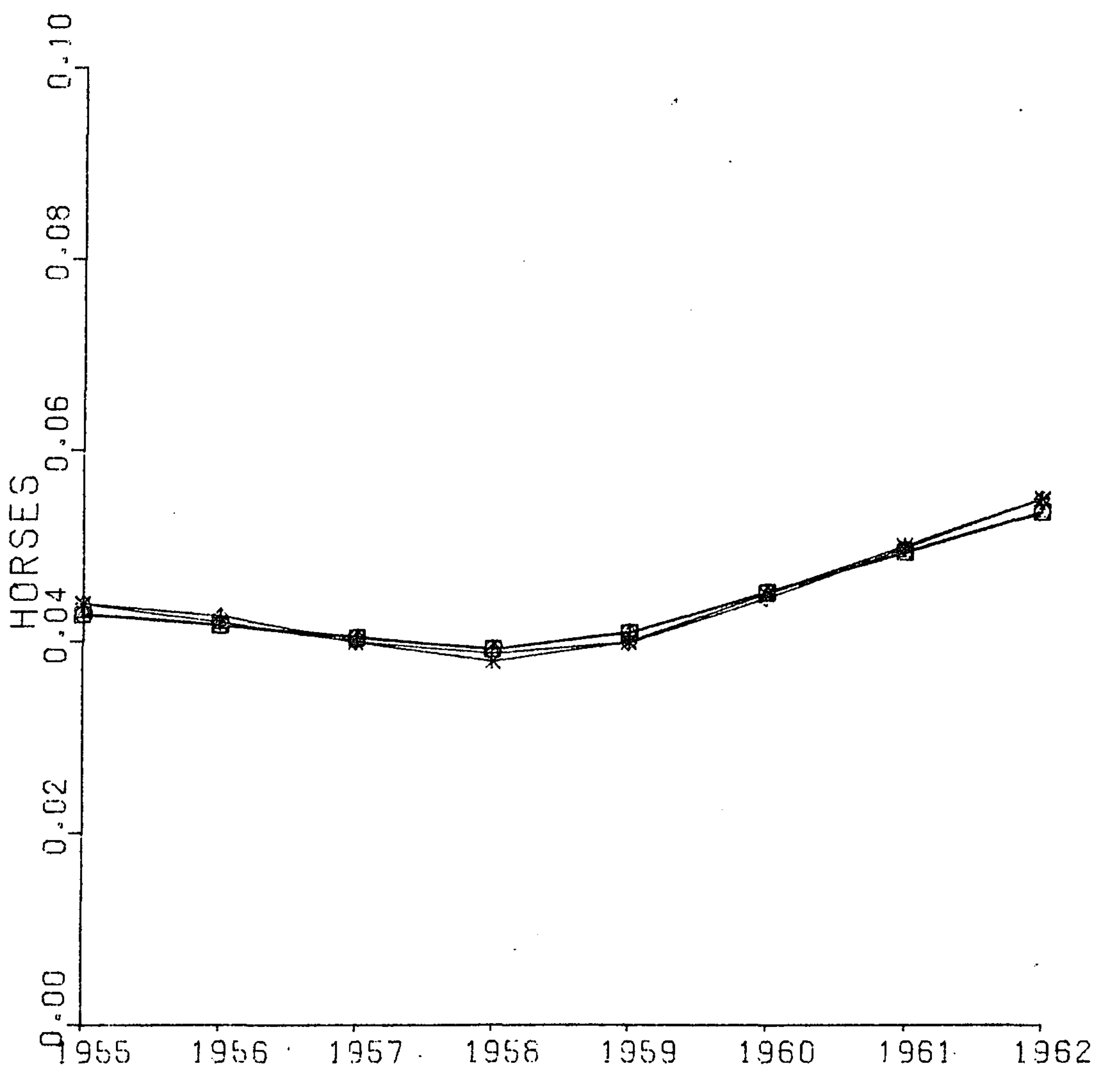

Figure B-12. Model output.

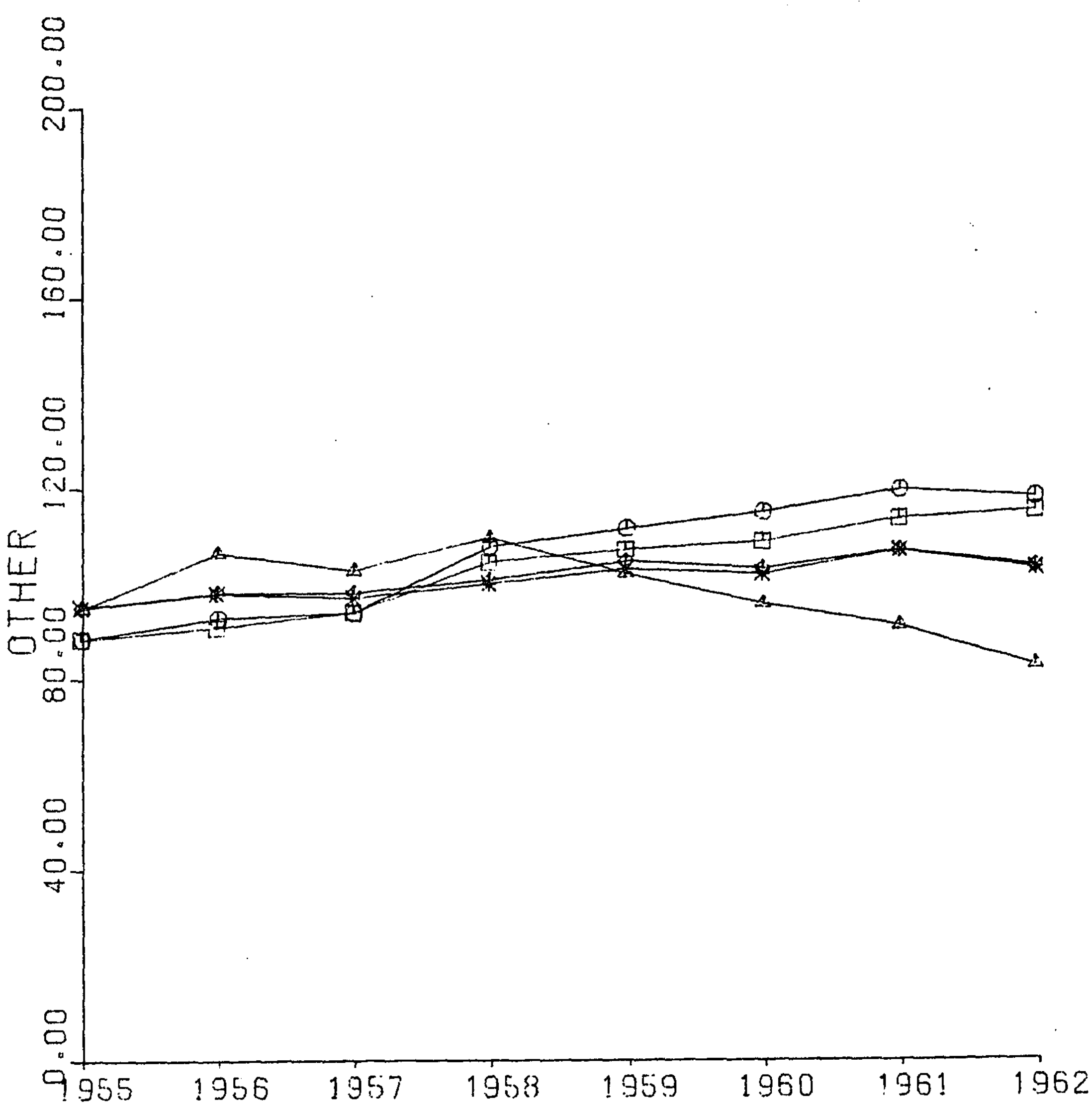

Figure B-13. Model output.

TABLE B- 1: PRODUCTION OF CORN

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	92.302	101.600	101.600	97.250	92.310
1956	100.215	113.100	112.600	104.000	101.300
1957	88.506	105.700	104.900	99.640	92.850
1958	101.136	104.500	99.000	100.700	107.300
1959	115.311	104.700	97.120	109.400	118.200
1960	111.402	100.100	90.760	109.500	114.100
1961	118.470	106.100	92.800	124.100	123.300
1962	111.951	99.800	96.670	125.700	111.700

TABLE B- 2: PRODUCTION OF WHEAT

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	27.966	33.910	33.930	31.310	27.970
1956	31.290	31.170	29.260	21.450	32.480
1957	28.739	30.010	30.450	24.700	29.530
1958	41.420	37.060	37.040	29.530	42.870
1959	35.584	30.720	29.320	26.910	37.400
1960	33.642	28.680	26.020	27.230	35.170
1961	39.996	33.330	29.320	34.170	40.680
1962	30.062	33.300	32.150	36.470	30.400

TABLE B- 3: PRODUCTION OF D BEAN

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	4.536	4.159	4.166	4.404	4.538
1956	5.389	5.086	5.092	6.088	5.346
1957	3.507	3.574	3.498	4.276	3.613
1958	5.226	5.231	5.186	6.303	5.360
1959	6.413	7.291	7.290	8.413	6.657
1960	6.247	7.075	7.236	8.016	6.375
1961	7.357	8.562	8.882	9.522	7.416
1962	7.391	7.990	8.325	8.845	7.245

TABLE B- 4: PRODUCTION OF S BEAN

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	3.036	3.104	3.108	3.031	3.035
1956	4.326	3.593	3.766	3.896	4.206
1957	5.412	4.274	4.379	4.316	5.444
1958	6.394	4.676	4.683	4.421	6.515
1959	5.782	5.484	5.526	5.321	6.031
1960	4.420	4.270	4.045	3.902	4.596
1961	7.410	7.338	7.404	7.536	7.363
1962	7.695	7.366	7.316	7.518	7.512

TABLE B- 5: PRODUCTION OF POTOES

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	5.540	5.642	5.641	5.654	5.539
1956	7.834	8.345	8.311	8.510	8.210
1957	6.260	6.452	6.444	6.520	6.760
1958	8.208	8.181	8.216	8.272	8.655
1959	7.350	6.174	6.208	6.210	7.909
1960	7.452	11.970	12.040	11.900	7.655
1961	9.264	8.993	9.052	8.828	9.858
1962	8.865	9.699	9.760	9.367	9.024

TABLE B- 6: PRODUCTION OF SUGBEE

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	.882	.857	.855	.864	.882
1956	.693	.702	.705	.716	.698
1957	.910	.913	.910	.921	.934
1958	1.107	1.166	1.168	1.174	1.153
1959	1.295	1.373	1.371	1.373	1.365
1960	.945	.990	.997	.984	1.014
1961	1.174	1.237	1.244	1.221	1.190
1962	1.076	1.145	1.153	1.110	1.099

TABLE B- 7: PRODUCTION OF HAY

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	3.118	3.074	3.076	3.079	3.116
1956	3.587	3.578	3.657	3.613	3.598
1957	3.343	3.548	3.590	3.468	3.433
1958	2.927	3.254	3.363	3.208	3.018
1959	3.491	3.954	4.180	3.862	3.595
1960	3.373	3.828	4.118	3.798	3.466
1961	3.227	3.769	4.068	3.835	3.295
1962	3.286	3.615	3.836	3.757	3.295

TABLE B- 8: PRODUCTION OF MILK

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	53.960	52.130	52.120	52.130	53.950
1956	53.650	54.680	54.720	54.700	53.830
1957	52.910	54.900	54.930	54.810	52.900
1958	52.160	53.830	53.810	53.710	53.040
1959	50.900	52.650	52.630	52.570	51.830
1960	51.730	51.270	51.260	51.100	50.800
1961	52.970	49.370	49.390	49.060	51.680
1962	56.060	46.340	46.450	46.060	55.450

TABLE B- 9: PRODUCTION OF BEEF

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	4.720	6.199	6.208	6.198	4.720
1956	4.500	5.563	5.562	5.574	4.675
1957	4.060	4.804	4.809	4.816	4.184
1958	3.890	4.427	4.419	4.432	3.966
1959	4.360	4.480	4.485	4.469	4.272
1960	4.410	4.878	4.868	4.875	4.197
1961	4.540	4.786	4.794	4.792	4.305
1962	4.670	4.484	4.498	4.492	4.568

TABLE B-10: PRODUCTION OF HOGS

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	2.840	2.765	2.757	2.759	2.840
1956	2.660	2.737	2.737	2.738	2.752
1957	2.370	2.371	2.372	2.374	2.478
1958	2.460	2.749	2.763	2.762	2.400
1959	2.740	2.973	2.981	2.973	2.700
1960	2.530	2.606	2.615	2.608	2.543
1961	2.560	2.657	2.659	2.651	2.516
1962	2.660	2.918	2.917	2.902	2.536

TABLE B-11: PRODUCTION OF EGGS

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	1.408	1.125	1.125	1.123	1.410
1956	1.388	1.238	1.237	1.236	1.408
1957	1.365	1.396	1.397	1.404	1.384
1958	1.305	1.453	1.453	1.457	1.339
1959	1.308	1.439	1.438	1.445	1.359
1960	1.199	1.348	1.346	1.350	1.250
1961	1.162	1.320	1.320	1.318	1.192
1962	1.154	1.157	1.159	1.159	1.178

TABLE B-12: PRODUCTION OF HORSES

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	.044	.043	.043	.043	.044
1956	.042	.042	.042	.042	.043
1957	.040	.040	.040	.041	.040
1958	.038	.039	.039	.039	.039
1959	.040	.041	.041	.041	.040
1960	.045	.045	.045	.045	.045
1961	.050	.049	.049	.049	.050
1962	.055	.054	.054	.054	.055

TABLE B-13: PRODUCTION OF OTHER

	ACTUAL	BASIC PROJECTED	COMPLEMENTS PROJECTED	CONST.VMP PROJECTED	CONSTRAINED PROJECTED
1955	95.000	88.410	88.400	94.830	95.000
1956	98.000	90.800	92.780	106.500	98.040
1957	97.000	93.940	93.830	102.700	98.050
1958	100.000	104.500	107.800	109.700	100.800
1959	103.000	107.100	111.600	102.100	104.700
1960	102.000	108.800	115.000	95.720	103.100
1961	107.000	113.600	119.700	91.080	107.000
1962	103.000	115.100	118.000	82.580	103.400