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A Generalized Simulation Approach to Agricultural Sector Analysis

With Special Reference to Nigeria

MICHIGAN STATE UNIVERSITY
East Lansing, Michigan
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16. Abstracts Because of the difficulties and uncertainties involved in solving economic development problems, researchers have turned to system simulation as a possible means of providing decision makers with information about the likely consequences of alternative resource allocations. A simulation study provides a group of time histories, each representing the outputs of a particular set of assumptions, exogenous variables, and policies. This report describes efforts to develop a general simulation approach to studying agricultural development. In order to develop such a simulation, it is necessary to model something in the real world. The Nigerian agricultural economy was chosen for this purpose since, for its modeling, it requires the construction of components which have widespread usefulness among both developed and developing countries. Consideration is given to the socioeconomic-environmental setting which the model is intended to simulate, the procedures of model estimation, refinement, testing, and validation. The major components of the Nigeria model are described, and the model is used in several policy experiments to provide both practical results and illustrations of the variety of uses to which the simulation model can be addressed. The requirements for practical implementation of this kind of model in developing countries are discussed.

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A Generalized Simulation Approach to Agricultural Sector Analysis

With Special Reference to Nigeria

Produced by the Michigan State University Simulation Team under U. S. Agency for International Development Contract No. AID/csd-1557—Agricultural Sector Models.

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PREFACE

THE DISCIPLINARY research work reported herein originated in the difficulties which arose in doing practical research on Nigerian rural development under the Consortium for the Study of Nigerian Rural Development. That consortium employed traditional paper and pencil and, occasionally, desk calculator projections in studying the impacts of alternative projects, programs and policies on the future development of the Nigerian agricultural economy. While the consortium experience was a fruitful one in addressing itself to the practical problems of donor and Nigerian agencies with responsibilities for promoting Nigerian agricultural production, a great deal of resources and time went into that effort. Roughly speaking, 30 professional man-years of a multidisciplinary character were used as the consortium research effort was practical problem-solving in its orientation. The approach was nonspecialized and not tied closely to any particular developmental theory or research technique. In short, it was the kind of common sense approach to agricultural development commonly employed by such agencies as the World Bank, FAO, AID and many more individualistic investigators. The difficulty was that, like all other such efforts, it was expensive, time-consuming and, at times, inexact and unspecified.

As a result of the consortium experience, interest was generated in the general systems analysis computer simulation ("general system simulation approach" for short) approach to such problems. A conference was sponsored by Michigan State University for the purpose of investigating possible uses of the system simulation approach in the study of agricultural development. AID officials attended, as well as a variety of people with experiences both in systems science and computer simulation and with studies of the consortium type. The conclusion of that seminar was that system simulation models were not yet well enough developed to be applied directly to studying agricultural development and problems. However, people were impressed with the difficulties and expense of noncomputerized projections and the Agency for International Development and Michigan State University undertook the present project, the results of which are reported herein.

The object of this project was to develop the general system simulation approach to studying agricultural development to a point where it would be applicable and operational. The original contract did not specify the country to be studied and did not require that the model become operational under the contract. Nigeria was selected because of widespread experience in Nigeria at Michigan State University and because of its diversity. The Nigerian agricultural economy requires, for its modeling, the construction of components which would have widespread usefulness among both developed and underdeveloped countries. In order to develop general system simulation models, it is necessary to model something in the real-world.

The selection of Nigeria for this purpose does not make her a guinea pig. Because of the civil war in Nigeria, relatively little time was spent there collecting information; Nigerian economists and governmental officials were simply too busy with the problems of civil war and postwar construction for it to be prudent to bother them with the fundamental disciplinary objectives pursued in this project. Though the objective was to develop generally useful model components and models which could be applied anywhere in the world, it is true to indicate that substantial progress was made in modeling the Nigerian economy and that this progress should be useful to not only the Nigerian agencies interested in agricultural development but to donor and lending agencies as well. Fortunately, both the World Bank and FAO are also taking steps to develop a general system simulation approach to the study of agricultural sectors, programs, policies and projects.

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It must be stressed, however, that while great progress is reported in this book on the construction of the model components and of models of the agricultural economy and, for that matter, rudimentary models of the nonagricultural economy as well, these models are not yet ready for application. A few of the subcomponents are ready to go. Most of them, however, require further modification and adaptation on the basis of the field work, additional data and, above all, interaction with either host or donor agency personnel. This follows because these components are constructed to be generally useful in a number of countries and were not based upon the more detailed kind of field work and study needed in Nigeria to make them applicable there.

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CHAPTER I

Introduction

RESOURCE ALLOCATION to attain development is vastly complex and affected by the dynamic interaction of a multitude of physical, social, economic, and political variables. It is well known that the development process can be highly insensitive to the overt efforts of planners to guide the directions of resource allocation. It is also known that certain development policies and programs can trigger spontaneous responses within the system which can lead to a sustained accumulation of benefits for the members of the developing society. However, the choice of efficacious development policies and programs is usually clouded by poor information, or lack of information, as well as by the inherent complexity of the process. Since the social opportunity costs of mistaken development efforts are high in many underdeveloped countries, improved approaches for evaluating alternative projects, programs and policies are much needed.

Planning development would be made easier if there were a common denominator for evaluating the variety of results arising from a single policy, project or program. Such a common denominator would need to be interpersonally valid in order to assess interpersonal transfers of goods and services. Another complicating aspect of development planning is that the outcomes of policies or programs often depend upon the timing and sequencing of policies or programs as much as upon the choice of program. Thus, even if there were a common denominator to ease the problem of evaluating multiple outcomes and consequences of policies, the problem of appropriately timing the actions would impede the simple application of the maximization rule.

Another complication in solving development problems arises when outcomes of actions are uncertain and knowledge is imperfect. Imperfect knowledge makes planning in any country a process fraught with uncertainty. Frequently, there is uncertainty about likely immediate and longer range effects of development strategies. Further, the degree to which policies aimed at one set of economic phenomena may have unintended side effects on other aspects of the society is often uncertain. The paucity of information available for decision making is often cited in developed countries, with even more frequent mention in less-developed countries. Poor communication facilities, especially prevalent in less-developed countries, often impede the accumulation of potentially available, relevant information which might otherwise provide a reasonably well-informed basis for decision making. Many project, program and policy alternatives impose a variety of damages on different people in order to confer a variety of benefits on others. Uncertainty with respect to the magnitude and incidence of such impacts makes it difficult to determine which decision rule to use in choosing a project, program or policy to prescribe as the "right" one.

Given these difficulties and uncertainties, researchers have turned to system simulation as a possible means of providing decision makers with information about the likely consequences of alternative resource allocations. Simulation is a step-by-step process of working out particular numerical time paths of variables, starting from a given set of conditions. A simulation study provides a group of time histories, each representing the outcomes of a particular set of assumptions, exogenous variables and policies. By trying a great variety of programs and policies and tracing their consequences through time, evaluation of each policy or program action can be made in terms of several criteria.

Paper and pencil simulations have been made of a number of countries, including the Nigerian agricultural economy. The Consortium for the Study of Nigerian Rural

Development (CSNRD), in fulfilling its objectives of evaluating agricultural development programs of USAID and the Nigerian government, undertook to make short-term simulations, i.e., to construct projections of consequences through time of various development alternatives. The projections included population, gross domestic and national products for farm and nonfarm, exports and imports, domestic food (including nutrition levels), and agricultural and nonagricultural investments. The projections were made for three time periods from 1970 to 1985 for three policy alternatives. These were:

1. Continuation of present policies and programs as they affect agriculture,

2. A shift as of January 1, 1968, of present policies and programs to give greater encouragement to rural development,

3. A shift to a set of policies and programs less favorable to agricultural growth than at present in order to make heavy investments in infrastructure to enlarge the public sector and to invest in nonfarm enterprises.

The results of these simulations are reported elsewhere (CSNRD 33), but are intended to provide decision makers with evidence of who would gain and lose, and the extent of the "bads" and "goods" as a result of following the alternative policies and programs under investigation.

Makeshift paper and pencil simulations are limited by the amount of time required to work them out through hand methods. The advent of large-scale electronic computers and associated techniques has made it possible to formalize the process of making such projections and save both time and money. Further, the computer provides the possibility for increasing the number of alternative policies and programs that can be evaluated. Thus, computer simulations provide the facility for answering many more of the "What difference would it make if..." type questions than are feasible with paper and pencil.

While computer simulation provides the method of making projections, systems analysis provides the approach to the development problem taken in this study of Nigerian development. A systems analysis approach can provide a comprehensive view of a complex system. In development planning, we are interested in isolating and formulating into a mathematical model those sectors and components of the economy and those physical, biological, economic and social relationships within them which are most important in affecting the development effort. The systems analysis approach, in the development context, emphasizes those relationships that can be affected by, or are vital to, the evaluation of either public or private development policies. In the process of formulating a system simulation model, relevant information, which often may not be available at one decision point, is brought together and incorporated into the model. Conflicting information is isolated and resolved, irrelevant or unimportant considerations are eliminated, and the most appropriate information is subsequently built into the model structure for use in analyzing alternative development strategies. The use of a computer to manipulate those complex social, economic and environmental relationships strongly affecting the performance of the economy allows for a more inclusive analysis of the direct and indirect effects of alternative policies, than do desk calculators, paper and pencil. This can substantially aid in critical resource allocation decisions in development agencies.

In recent years, economists have made use of policy simulation experiments with macro-econometric models to evaluate the effects of alternative economic policies on certain aspects of behavior of the economy of an entire country. Naylor has reviewed some of these macro-econometric model efforts and concluded that there are a number of methodological problems associated with policy simulation experiments with econometric models for which solutions do not presently exist (Naylor, 1970). Some of these problems will be discussed in the third chapter where conventional analysis of simultaneous equilibrium equations and maximization techniques will be compared with the system simulation approach utilized in this study.

Some of the pioneering efforts in application of the system simulation approach to underdeveloped countries are those of Edward P. Holland and his associates. Holland and Gillespie's works on the Indian economy (Gillespie and Holland, 1963), and Holland's Venezuelan economy model (Holland, 1966), are examples of macro-models that illustrate the complexities of attempting to simulate an entire economy. The Ligomenides, Manetsch and Ramos simulation model of the cotton sector of the North-eastern agricultural economy of Brazil (Ligomenides, et al., 1967), illustrates the application of simulation under conditions not unlike those found in other under-developed countries.

Each of the earlier simulation models has provided experience and insight useful in developing appropriate means for simulating the economy of other countries. With this background, the simulation techniques deemed most appropriate for the given problem and computation facilities were selected. However, the actual quantification of those models has been heavily dependent upon available research literature and knowledgeable persons that can describe the current environmental and economic interactions, as well as many modernization alternatives in the country of interest.

A substantial amount of methodological progress in simulation techniques has been made. However, a seminar specifically held to assess the feasibility of utilizing simulation models in development planning at Michigan State University, in February 1966, concluded with the consensus that "simulation models are of questionable operational value for economic development research at this point in time,...and efforts are needed to adapt and extend existing simulation models for use in economic development."1/

Research Objectives

One of the consequences of the simulation conference was a decision by AID to support an interdisciplinary research project at Michigan State University directed toward developing a system simulation capability, including specific model components, which would have relevance to development environments in countries being assisted by AID. Thus, the research objective was to "develop simulation models which will prove useful to policy and decision makers in formulating programs and projects to improve the productivity of the agricultural sector--."2/ The main design objective was to develop an aggregate model (useful in many countries), capable of being partitioned and extended to include additional, detailed submodel components which would handle more detailed decision making and policy problems of concern to agricultural development agencies. Because of Michigan State University's experience in Nigeria and then-ongoing research efforts being conducted under the auspicies of the Consortium for the Study of Nigerian Rural Development (CSNRD), the Nigerian economy

1/ *Report on the "Workshop on Possible Use of Simulation Models by CSNRD for Nigerian Agriculture" based upon a conference sponsored by Michigan State University, February 11 and 12, 1966.*

2/ *Agency for International Development Contract No. AID/csd-1557, p. S-2.*

was selected. However, the objective was not to produce an operational model of the Nigerian economy. Such a model would require more field work, more Nigerian participation and more interaction than provided in the AID/Washington-MSU contract. Initially, the Nigerian beef industry was selected as a major component of the Nigerian economy which could provide an initial test of the feasibility of a more global undertaking--simulating an entire agricultural economy. If the initial phase of the study proved to be worthwhile, the remainder of the economy was to be modeled with stress on producing components of general international usefulness.

The objective of the entire effort was to develop, and the initial contractual obligation was to create, a system simulation capability and assess the feasibility of its potential implementation as a planning tool for many countries, both developed and underdeveloped. Any implementation effort in Nigeria or other countries was to be subsequently established and funded in a manner then considered most feasible. Since there was no responsibility for application of the model, the project was funded through the Technical Cooperation and Assistance Office of AID rather than through the "Nigerian Desk" of AID. There is no contractual obligation to be directly useful or helpful to Nigerian or USAID/Lagos planners or policy makers. However, a faith in system simulation was expressed by the Technical Assistance Bureau (TAB/AID/W) in funding the projects and by MSU in allocating scarce research personnel to the project: system simulation has great potential utility for host and donor agency decision makers and policy makers, which could be developed. This faith is justified, it is felt, by the research results presented herein. In addition to fulfilling the objective of the contract of developing computer simulation as an approach to project, program and policy design, the specific model for Nigeria holds considerable promise for application by both Nigerian and concerned donor and grantor agencies.

Procedures

An interdisciplinary research team--consisting primarily of agricultural economists, systems scientists and computer programmers but also including a political scientist, and technical agricultural and sociological consultants--was assembled at Michigan State University. By utilizing a core staff of quantitatively oriented agricultural economists and systems scientists who were able to consult with other professionals having Nigerian experience in crop and animal sciences, anthropology, nutrition, economics, agricultural economics and policy, the general framework of the system to be simulated was specified and the major kinds of questions which a systems model might help address were identified.

In this "problem definition" phase, the primary functions and mechanisms of the system were specified, the appropriate measures of systems performance were tentatively diagnosed, and the alternative means of policy variables available for achieving development objectives were specified. This required the creative interaction among decision makers, planners, systems analysts and other specialists. Previous Michigan State University work in Nigeria and the ongoing Consortium for the Study of Nigerian Rural Development (CSNRD) research efforts had already produced substantial information about the country. Further, these efforts also provided many useful contacts, with both American and Nigerian individuals who were knowledgeable about African agricultural and industrial development. The CSNRD collaborations with AID, FAO, and Nigerian planners and policy makers provided a fairly clear picture of the current governmental and planning institutions related to the agricultural economy and to the tools they use to influence the economy. As a consequence, the major policy questions in the corresponding relevant sectors, interrelationships and variables in the Nigerian economy were isolated more easily than might otherwise have been the case. Fortunately, modeling Nigerian agriculture requires most of the components needed to model any less-developed country, the exceptions involving mainly irrigation and mechanization.

Specifying the relevant policy-making clientele and their most important questions determined which sectors and/or interrelationships needed particular attention within the model. (The major sectors and flows in the simulation model are shown in Figure 3.2 of Chapter III.) Emphasis in the model is on the agricultural sector. Since agriculture contains over half of the productive resources in Nigeria (contributing 65 percent of the gross domestic product and 66 percent of Nigerian exports in 1962-63), its role and future growth will be very important, a situation similar to that in many other less-developed countries. Some planners are interested in evaluating alternative policies affecting regional production specialization and trade. These, typically, involve likely farmer responses to various economic incentives or government assistance projects, etc. Consequently, the model has a commodity orientation emphasizing the most important export crops.

To simply consider questions related to regional specialization and interregional trade, two agricultural regions (north and south) were delineated. However, several ecological zones within each region were also differentiated to allow the model to assist planners more readily at the regional and state levels. In conjunction with the specification of the main components, sectors and flows to be incorporated in the simulation model, the basic political decision mechanisms and their point of impact on the agricultural development and investment process in the economy were identified. (See Figure 3.3 of Chapter III.) The points of impact range from input allocation decisions to production results, through the marketing process to consumption. The flows of material, money, price information and regulatory activities were specified. Thus, a general policy mechanism that applies to virtually any agricultural commodity produced was envisioned. In the Nigerian economy, the mechanism was specifically applied to staple food crops, livestock and the export crops, i.e., oil palm, groundnuts, cotton, cocoa and rubber, in the agricultural production and marketing sectors of the model.

The global model consists of three integrated submodels: (1) the Northern annual crop-beef model; (2) the Southern perennial-annual crop model, and (3) the nonfarm sectors model. Components of the Northern annual crop-beef model simulate the production of beef and subsistence food, and the production and marketing of groundnuts, cotton and food for the cash market. The components are structured to represent four distinct crop regions defined on the basis of differing climatic and soil conditions in the North. In addition, components were developed to simulate land allocation, modernization, population, and processing. These components make it possible to simulate a large number of activities that can be used in a wide range of problem situations in many different countries. The intent of this building-block approach was to attain applicability in a wide range of countries. Thus, applications are not limited to Nigeria. Subsequent work in applying the model components is already under consideration in other countries, developed as well as less-developed. It must be stressed that application, wherever applied, will require field work, modification, and further testing.

The Southern perennial-annual crop model contains components that simulate the production and marketing of cocoa, tobacco, rubber, palm products and food for subsistence and the cash market. The components are structured to reflect the competition and interaction of the five crops in four different regions representing different ecological and natural conditions. The other major components of the

Southern model include land allocation-modernization decisions, population and processing. The components were developed to simulate general conditions and can be used to study tree and annual crop production anywhere in the world. Also, the Northern and Southern models can be run independently or as a single model incorporating interregional trade between the two regions, another characteristic of its worldwide applicability.

The nonagricultural model is basically an input-output table with dynamic consumption and investment demands. It calculates employment requirements, import-export balances, government revenues and the components of the national income accounts. It can interact with the agricultural models receiving data on agricultural inputs, exports and investments, and determine the quantity of food and other agricultural raw materials demanded by the nonagricultural sectors. The addition of some very simplified agricultural sectors to the nonagricultural model can modify it for use as an independent macro-model of the entire Nigerian economy.

The detailed agricultural models will provide a wide range of numerical outputs of the agricultural sectors, including contributions to gross domestic product (GDP), exchange earnings, tax revenues, employment, per capita income and nutrition and price levels of food. The nonagricultural model will calculate aggregate levels and growth rates in GDP, import requirements, employment, import-export balances and nonagricultural per capita income. A wide range of policies can be tested with each submodel or with the global model. These range from testing the impact of such programs as tsetse fly eradication or increasing oil exports on the economy's performance. The specific programs and policies which we have tentatively evaluated will be discussed in conjunction with the exposition of the model subcomponents in subsequent chapters.

The type of research organization which was possible with this simulation approach made it feasible to incorporate a large number of part-time contributors and semi-autonomous research efforts into a comprehensive package. The research team was organized under a director who contributed greatly in defining the objectives of the project. The initial location of the research effort at Michigan State University was intended to make use of the excellent computer programming facilities then available, and to better accommodate faculty members and graduate students involved part-time in the simulation effort. The main members of the team contributed from the initiation of the project to completion. Graduate students who worked on the project as part of their dissertation efforts were required to contribute objectives to the overall project while maintaining individual initiative and responsibility in pursuit of their own research objectives. The building-block approach to constructing the global model allowed persons to enter and leave at various stages of model development without seriously impairing the project's progress. This approach of constructing one component of the model after another and providing for interactions between them was followed until the model was built. Not only did the building-block approach aid in the systematic organization of the team effort, but it also made it possible to apply subcomponents of the model to particular situations where the interactions with other components can initially be ignored. For example, for specific questions concerning beef production in a given country, the beef component (block), of the model can be run separately from the rest of the model. Or, if a country is concerned with annual crop production programs and policies, the annual crop model can be run separately from the remainder of the model to answer those specific questions. Other parts (blocks), of the model can be used in a similar manner.

In subsequent chapters, we will consider in detail the socioeconomic-environmental setting which the model is intended to simulate, the procedures of model estimation. refinement, testing and validation. Then, the major components of the Northern, Southern and aggregate economic submodels will be described (with detailed mathematical appendices available for the technical reader). The total model will then be utilized in several policy experiments to provide both practical results and illustrations of the variety of uses to which the simulation model can be addressed. In conclusion, we will evaluate our research success to date and consider future research needs and the requirements for practical implementation of this kind of a model and its various components in less-developed countries.

CHAPTER II 1

The Regional Setting of the Model

TO PROVIDE A CLEARER PICTURE of the environmental setting which we are attempting to simulate, let us sketch the salient features and problems of agricultural development in Nigeria and indicate those features which Nigeria has in common with other agriculturally dominant, developing countries.

The Geopolitical Setting

The Federal Republic of Nigeria is the most populous country in West Africa with an estimated total population of 55,670,000 (1967), within an area of 356,669 square miles. Nigeria extends inland from the eastern end of the Gulf of Guinea deep into the West African Savannah. Most of Nigeria is a low plateau: the coast is swampy with chains of lagoons and creeks, but the land becomes more rolling and sometimes even rugged north of the littoral. However, the uplands seldom reach above 3,000 feet. The most extensive highland is the Jos Plateau, which is about 6,500 feet in height. The most important Nigerian rivers are the Niger with its two major tributaries, the Kaduna and the Benue, and the Cross in the East. Partially navigable by steamers, these rivers serve as very important means of transport.

Nigeria has a relatively good network of roads and railroads which connect the agricultural hinterland with the major seaports of Lagos, Port Harcourt and Calabar. Southern Nigeria is served with a fairly elaborate set of feeder roads which connect the outlying villages to the major trunk roads and regional population centers.

Nigeria is divided politically into 12 states and the Federal Territory of Lagos, where the national capital is located. The major developmental programs are administered by the individual states, with the Federal Government providing leadership and coordination. As in most developing countries, the public sector is overburdened with many functions and responsibilities hampering its effectiveness. This underscores the importance and urgency of revamping and expanding the country's public administration and managerial capacity.

The Population

The Nigerian population has four attributes characteristic of other developing countries. First, the total population of Nigeria has been growing at an increasing rate; this is expected to continue in the foreseeable future due to a general decline in the death rate and a stable birthrate (unless effective family planning

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1/ *Several extensive discussions of the Nigerian socio-economic and environmental situation are available. These include FAO (1966), CSNRD (1969), Helleiner (1966), Stolper (1966) and others.*

were introduced). The death rate has declined rather dramatically with the introduction of better public health and sanitation programs. The annual average rate of population growth is estimated to be near 2.5 percent. If it continues at this rate, the population would double in approximately 28 years.

Second, population density is unevenly distributed. The greatest density occurs in the East, with some concentration of population in the West and in a few major northern cities, such as Jos and Kaduna. However, only about 20 percent of the people live in urban areas. In many parts of Nigeria, the population density is very low; some sections have almost no permanent human habitation.

Third, there has been a considerable amount of population movement throughout the country. These population movements can be classified as: (1) permanent migration from rural areas to major towns of a region (especially of young people between the ages of 16 and 24); (2) seasonal migration of members of the northern rural labor force to accomodate the demand for harvest labor in the South; (3) movement of the nomadic Fulani herdsmen from North to South as the tsetse fly recedes southward in the dry season.

Fourth, the population is ethnically and linguistically diverse. Over 250 identifiable groups with different languages, cultures and social organizations populate Nigeria. Five major tribes are regionally dominant--the Hausa and Fulani in the North, the Yoruba in the West, the Bini in the Midwest and the Ibo in the East.

Geographical Regions and Ecological Zones

Nigeria can be divided into two distinct agricultural regions--the northern Savannah and the southern Rain Forest regions. The North consists of the North Western, North Central, Kano, North Eastern, Kwara and Benue Plateau states. The South consists of the remaining six states: the Western, Mid Western, Lagos, Central Eastern, Rivers and South Eastern states. In turn, each region can be divided into special ecological zones distinguished by their crops cultivated, climate, soil and natural vegetation. These ecological zones are not necessarily contiguous. They overlap considerably, since geographical changes are gradual and subtle, but these are identifiable and reasonably distinct. The two basic geographical features that determine the agricultural crops and livestock activities in these zones are: (1) climate, and (2) the natural vegetation and soil types.

Climate

Rainfall and temperature are the two most important climatic features. Nigeria's rainy season lasts from April to November in the South and from May to October in the North. It is dry the rest of the year.

Total annual rainfall in the North averages about 40 inches, although it is much higher in the Benue Plateau. In the far North, rainfall may be less than 30 inches. The South receives much greater amounts of rain, averaging about 80 inches annually, with the coastal rainfall averaging about 120 inches (Figure 2.1). An equally important feature is seasonal distribution of the rain. As seen in Figure 2.2 and Figure 2.3, which show the isohyets of the wet and dry seasons, the North receives hardly any precipitation in the dry season, whereas the South receives a fairly substantial amount throughout the year.

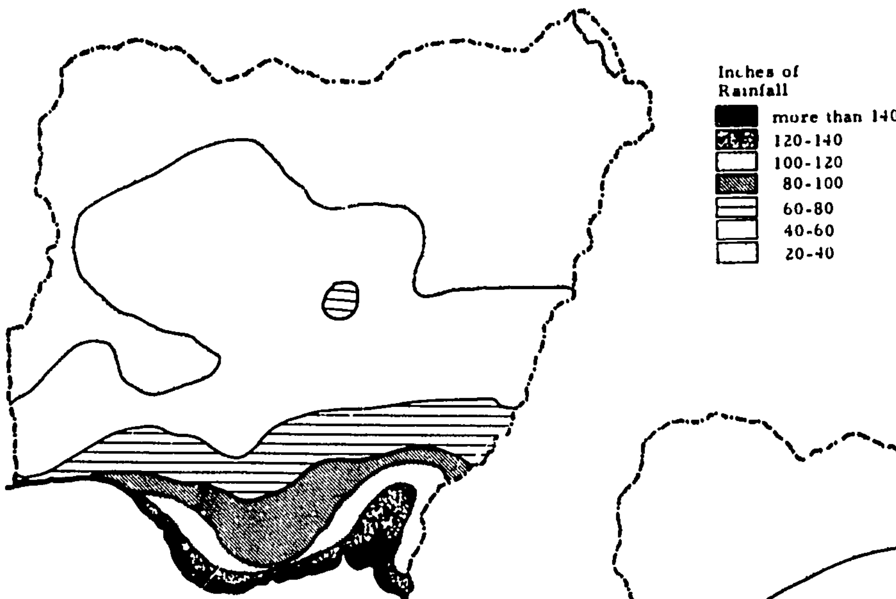


Figure 2.1. Annual total rainfall in Nigeria.

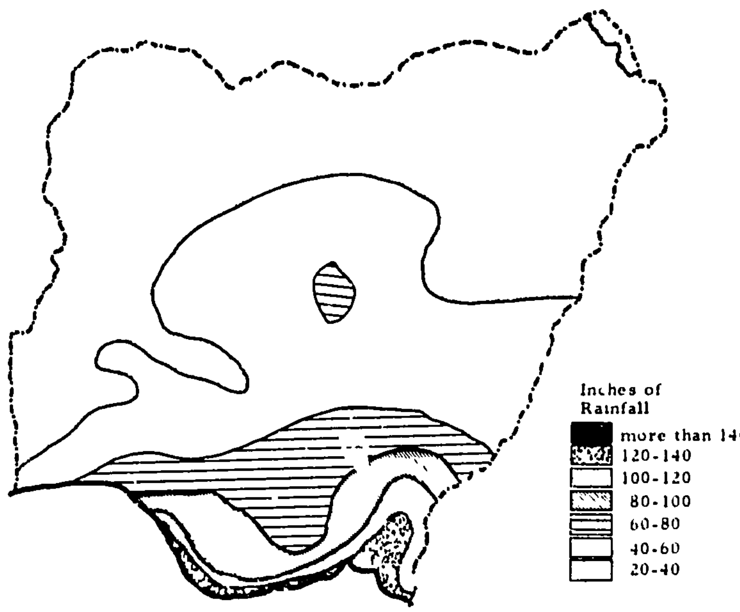


Figure 2.2. Rainfall in Nigeria during the wet season.

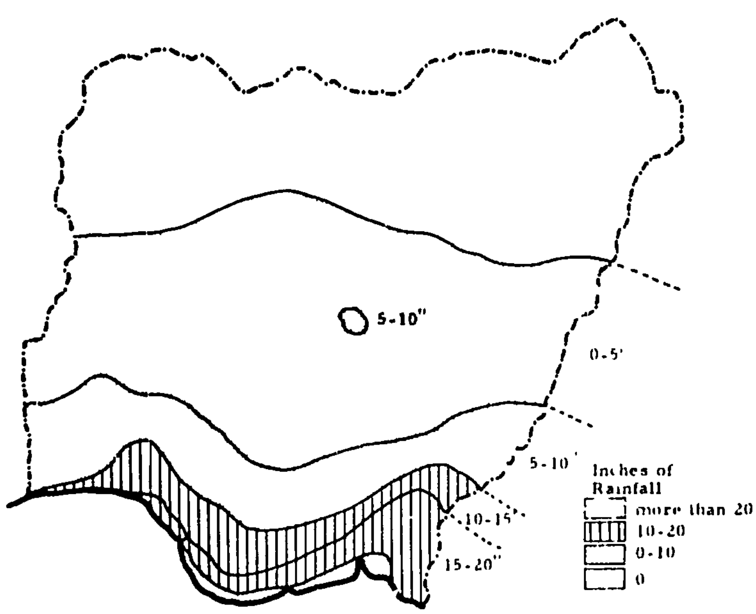


Figure 2.3. Rainfall in Nigeria during the dry season.

The annual temperature range varies between 75°F and 95°F, with the highest temperatures occurring between February and April in the South, and between March and June in the North. Humidity ranges vary greatly throughout Nigeria. In general, coastal influences in the South result in higher humidity there than in the North where variances depend upon seasonal rains.

Natural Vegetation

The climate and the geology of the land determine the natural vegetation and soil types. These, in turn, determine the agricultural adaptability of other nonindigenous commercial crops and livestock that may be introduced. Human activities, land settlement patterns, man's present and past patterns and intensity of land use also modify its natural flora and fauna.

The natural vegetation and soil types of Nigeria can be divided into two basic categories--the Rain Forests and the Savannah--which correspond approximately to the North-South agricultural regions defined in the model. Again, the distinguishing feature from South to North is the vegetation change from the lush Rain Forest to the sparse Savannah associated with the increasing scarcity of precipitation.

In general, tree crops such as cocoa, rubber, oil palm and food crops such as yam and cassava, which require long growing seasons, do relatively well in the South due to higher humidity and a longer rainy season. However, these same crops do less well along the coast due to the excessive amount and intensity of rainfall and in the North where rainfall is scarce. In the North, the Savannah provides a fairly good natural habitat for grazing animals and crops, such as guinea corn, cotton and groundnuts, which require a hot, dry ripening period.

Nigerian farmers also rear a few animals, mostly chickens and goats. In the North, Fulani herdsmen graze approximately 10 million cattle in the tsetse-free area in a seasonal migratory pattern.

The Agricultural Economy

The Nigerian economy is basically agricultural. Agriculture is the largest generator of national income, government revenue and foreign exchange, contributing about 65 percent of the gross national product and employing over 70 percent of the total labor force. At present, large commercial plantations and government-sponsored settlement schemes play a very small role in the total agricultural production of the country.

Nigerian agriculture, like that of other developing countries, has three major roles to play in the economic well-being and development of the country. First, the people must be fed adequately and nutritionally. The solution to the food problem depends crucially on the interplay between the effective consumer demand, the food supply response of producers and the adequacy of the distribution system. The general population must maintain an adequate income level to effectively demand and purchase food. In turn, the price of food must be high enough to provide sufficient incentive for producers.

Second, in the next decade or so, agriculture will probably be the chief sector for providing employment opportunities and an adequate income level for most of the country's population and labor force. The role of industrial and service sectors in national development is still fairly limited due to their relatively low capacity for labor absorption.

Third, in the longer run, agriculture must also be one of the major sources of revenue and resources for the transformation of the country's economic structure. This may be true despite the increasing significance of other economic activities providing employment and also generating income and revenue, e.g., the Nigerian petroleum industry.

The agricultural economy encompasses over 5 million smallholders who typically cultivate 2 or 3 acres in the South or 8 to 10 acres in the North to supply income and household food consumption needs. Three distinctive features epitomize the organization and nature of the smallholder agricultural production of Nigeria: (1) a large proportion of the agricultural production (especially the staple food crops), is consumed within each household, with the surplus generally marketed locally; (2) there is a considerable amount of regional specialization of food production, with the degree of specialization and internal trading within each region related to the development of the transport system and the market network in each ecological zone, and (3) the smallholders cultivate some major export crops which are marketed almost exclusively on the world market, providing a great amount of foreign exchange. These agricultural production features are quite common in many developing countries.

Although the Nigerian farmers are typically depicted as small-scale producers, they are not necessarily homogeneous. There is, in fact, a pronounced skewness in the distribution of farm sizes, income levels and total farm and nonfarm asset holdings among the smallholders. The larger smallholders may average about 50 acres of crop land. By Western standards this may be considered small, but their relatively large scale of operations is significant in Nigeria, giving them more economic power, influence, leverage and better access to market information and modern inputs. Likewise, their consumption, savings and investment patterns differ from other smallholders. In a developing country, where there is always an excess demand for modern inputs and technical assistance, the inequitable distribution of farm size and income becomes even more important. This economic feature affects the impact which various government production-incentive policies may have, as well as the resulting collection of revenue and taxes from them.

In our model, the North-Savannah agricultural region is divided into four distinct components related to cropping subregions differing in their climate and ecology. They are: (1) land where groundnuts and food crops (primarily grains in the North), are produced; (2) land where cotton and foods are produced; (3) land where cotton, groundnuts and food are produced, and (4) land in the Middle Belt between the North and South where only root food crops can be produced. There is also a fifth region in the North, overlaping the preceding four subregions, which provides the grazing and crop land residues for the livestock industry. (See Figure 2.4.)

Similarly, the South-Rain Forest agricultural region is divided into four ecological subregions or production zones: (1) land where cocoa and food are produced; (2) land where oil palm and food are produced; (3) land where oil palm, rubber and food are produced, and (4) land where only food or other annual cash crops are produced. (See Figure 2.5.)

Figure 2.4. The four crop-regions of the northern model.

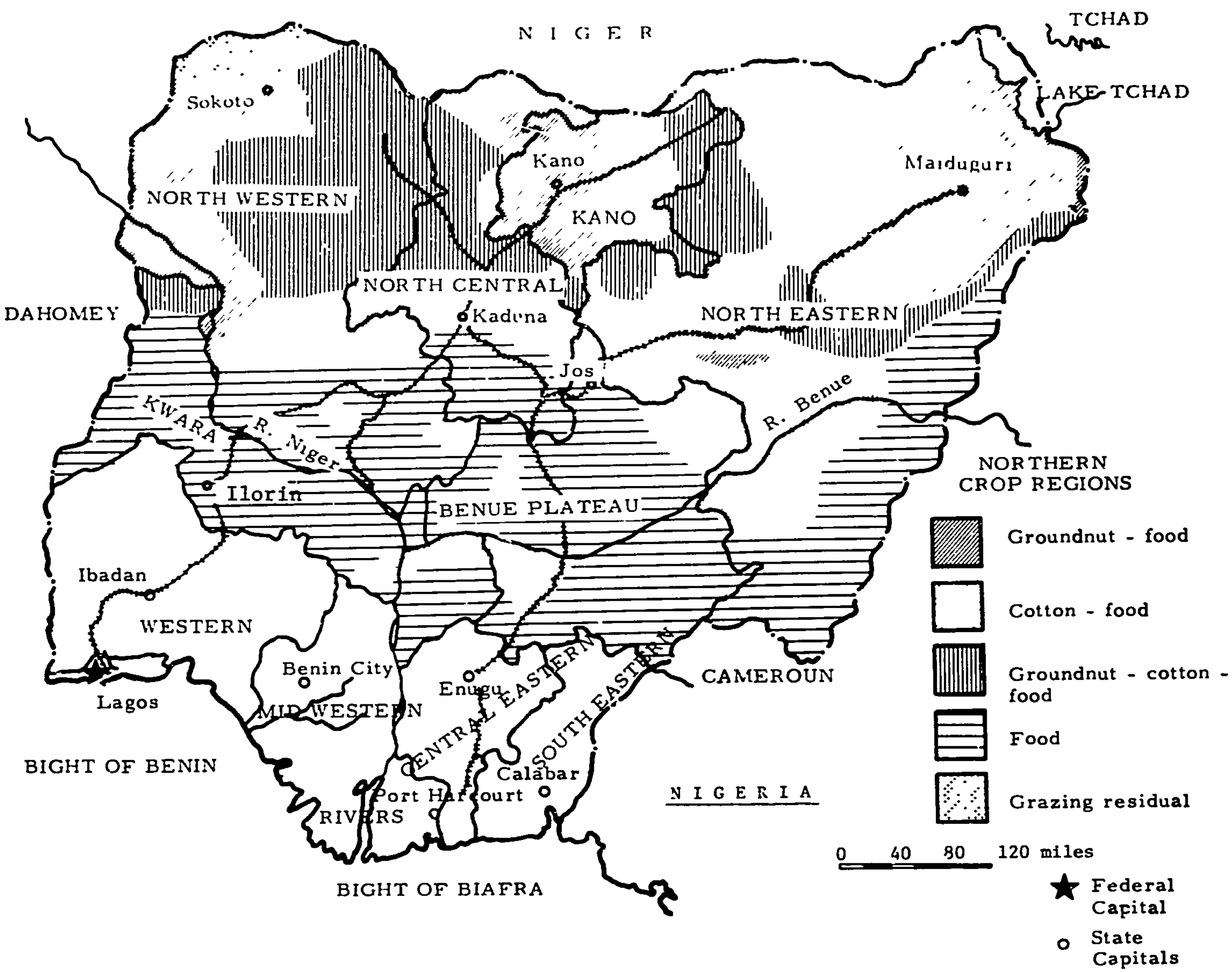
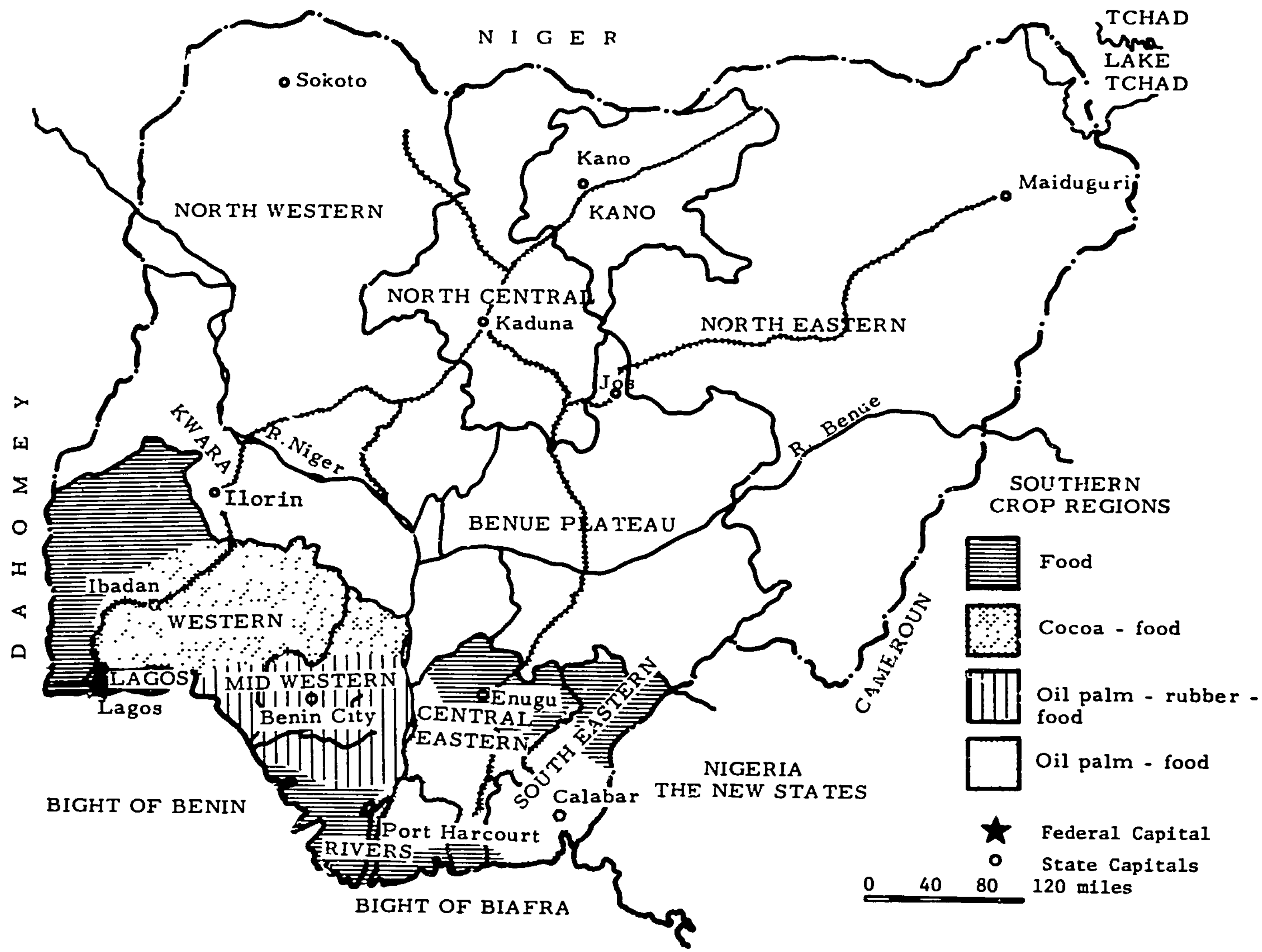


Figure 2.5. The four crop-regions of the southern model.



In many instances, regions similar to each of these agricultural regions and ecological zones may extend across entire countries, while in other cases, another country may have two or three ecological zones within its national boundary. For example, Chad and Niger have geographical features comparable to those in Nigeria's North. The southern regions of Ghana and Ivory Coast correspond to Nigeria's South, and their North corresponds to Nigeria's. On the other hand, all of south Thailand and Malaya correspond to Nigeria's rubber-oil palm-food ecological zone.

It should be emphasized that, in the North, the primary resource allocation problem of the respective ecological zone is the selection of annual food crops cultivated for household consumption or the cash market crops, such as groundnuts and cotton. In the South, the resource allocation problem is selecting among annual domestic food crops and perennial tree crops--cocoa, oil palm and rubber.

Three fundamental behavioral or resource relationships are incorporated into the Nigerian simulation model: (1) the first order of priority for farmers in each ecological zone is to meet their subsistence food needs before allocating other resources to cash crop production (however, the model also incorporates an input-output mechanism for modifying this behavior when self-sufficiency is of less important concern); (2) in the North, the limiting factor of production is labor, and in the South, the constraint is the availability of arable land; (3) the price of food is determined endogenously by supply and demand, whereas, the producer prices of the major cash crops are determined exogenously by the commodity marketing boards and the world market.

Problems and Prospects of Nigerian Agriculture

Nigeria is confronted with many of the same problems that beset other agriculturally dominant countries. Nevertheless, the future of Nigerian agriculture is bright and full of unrealized potential despite its present paradoxical position. Nigeria still has an appreciably unused and underutilized productive capacity. However, returns to land, labor and capital have been relatively low due to the risks and uncertainties involved in adopting improved production technology and the government's policies of maintaining "low" producer prices for the major cash crops. These factors have led to low incomes and a subsistence agriculture.

Marketing boards in Nigeria have a very pervasive influence on the country's total agricultural economy. The boards are the sole buyers of the major Nigerian export crops--cocoa, groundnuts, cotton and oil palm products. The only exception is rubber. The boards are served by a network of licensed buying agents who act as local buyers of the produce. They have four basic responsibilities and functions: (1) to handle and market the produce internally; (2) to collect taxes and revenue for each state and the country; (3) to accumulate funds to stabilize the domestic price, acting as a buffer to fluctuations of the world price, and (4) to accumulate a surplus, which is used as a very important source of development funds for various regional agricultural and nonagricultural developmental projects.

These roles and functions have recently come under heavy criticism. The main contentions against them are that: (1) heavy government taxes have depressing production and income effects against the producers; (2) surveillance of the local buyers and product inspections are inadequate, and (3) performances and returns of the boards investments in various developmental projects have been poor. The major concern here is the pricing policy.

The present marketing board pricing policy of low producer prices has two adverse effects on the economy. The low price the farmers receive for their produce decreases their income level and their total demand for other goods. Most farmers are in no financial position to purchase these commodities when their income is low, nor are they willing to expand and adopt modern methods that require more capital, even though they obtain higher yields.

The government can use two basic policy instruments to increase the farmers' profitability and stimulate increased production. Production campaigns can encourage the farmers to adopt new technology and production methods. Adoption can be further stimulated by providing (or subsidizing) the needed material, cash or low-cost credit. The producers' price or income can be increased. However, the impact of these instruments on farmers will differ according to individual enterprise situations and the size and scale of operations. While it may be true that the profit equation is increased absolutely whether the price of the output to the farmer is increased or the cost of the production is subsidized, the impact differs because the timing and risks associated with the two instruments are different. If the farmer is presently producing a particular commodity, an increase in the producer price has an immediate impact on his current income. On the other hand, if he is not producing any commodity (for example, his cocoa trees may not yet be productive), the increase in producer price would have no direct effect on his current income, but a cash grant would immediately affect his situation.

The government also must provide the basic infrastructure, social amenities and ancillary services that directly affect agricultural production and marketing and the general welfare of its citizens. For example, for sustained growth and development, roads, schools, training institutes, research facilities and health facilities must be built or expanded to service the rural-agricultural sector. Each of these supporting programs has its own cost-benefit matrix, total manpower and financial requirements, duration and timing of implementation and probabilities of success. But all are related functionally and structurally; their costs and benefits may be joint. Some may have to precede others while still others may have to be implemented simultaneously to take advantage of the complementary or synergistic effects. In the empirical context, each development program may be administered by different departments or ministries. For example, the export pricing policy is controlled by the commodity marketing board. The fertilizer distribution program is run by the State Departments of Agriculture and the construction of feeder roads is done by the Ministry of Public Works. We should not minimize the immense problems of organization, coordination and cooperation that must be solved for effective administration of development strategy.

CHAPTER III

The Systems Analysis Approach and Simulation Methods

BEFORE DESCRIBING the general system simulation approach, we will first consider the complex nature of economic development. Then we consider some difficulties with the use of certain specialized techniques for analyzing complex development problems. The specialized techniques to be considered are: (1) statistically estimated sets of simultaneous equilibrium equations; (2) maximization models, and (3) other specialized techniques. Finally, we will describe the general system simulation approach employed in developing our model.

Complexity of Problems and Their Solutions

A reason frequently given for using a systems approach in attacking problems of development is the complexity of the problems under investigation. Development problems generally involve attempts to attain a relatively large number of objectives with relatively few means. While modern society is usually taken as the ultimate in complexity, the growth of a relatively less-developed economic system is also complex. Interactions within and among traditional, transitional and the modern sectors must be considered.

Four fundamental difficulties may be encountered in selecting the policy, program or project which will best solve a given complex development problem. They are: (1) the absence of a common denominator among the "goods" being sought and the "bads" being avoided; (2) the absence of interpersonal validity in a common denominator which may be available; (3) the absence of the second-order conditions necessary to maximize the common denominator, and (4) the absence, in the presence of imperfect knowledge and foresight, of an appropriate rule for choosing the right policy, program or project among open alternatives. In addition there are difficulties with respect to: (5) kinds and sources of information; (6) conceptual inadequacies of various disciplines, and (7) the feasibility of finding solutions to the systems of equations which make up a model.

Solving problems involving the attainment of multiple objectives would be easy if there were a common denominator to reduce all objectives to a single dimension or objective function. Reducing the multiple objectives involved in a complex development problem is the first of the four difficulties referred to earlier. Such a common denominator is needed to solve a problem with maximizing techniques, following the procedures of the ordinary differential calculus or linear programming. The second difficulty arises from the requirement that such a common denominator be interpersonally valid if it is to be used to evaluate the consequences of projects, programs and policies which impose losses on some in order to confer benefits on others. In the initial absence of such a common denominator or welfare function, it is helpful for investigators to provide decision makers with information on the consequences through time of implementing alternative policies, programs and projects. This can be done by making projections via a computerized simulation model of the system under study. A simulation is a means for computing the consequences through time--in view of what is known--of contemplated courses of action. The consequences, including their distributions among the subjects of policy application, can be considered jointly with program designers and policy makers with the intent of further developing, extending and refining knowledge of the various "goods" to be attained and "bads" to be avoided.

For instance, noncomputerized projections have been used for many years in governmental and private agencies by decision makers and staffs or investigators to explore the trade-offs among multiple objectives and multiple adversities. Computerized projections can be used in the same way. It is in this "give and take" between decision makers and investigators that normative knowledge about goods and bads accumulates to a point at which the necessary common denominator is known. In this sense, the general system simulation approach is a way of acquiring normative knowledge provided it involves creative interaction between investigators and decision makers. The interaction may increase interpersonally valid normative knowledge to a point at which the simulation model itself can be revised to maximize a common denominator with substantial interpersonal validity, thus handling both the first and second fundamental difficulties referred to above.

The third fundamental difficulty in solving practical development problems is that of determining the optimum order in which projects should be executed within a program, the order in which programs should be executed within a policy or the order in which various policies should be executed in developing a sector or an economy. When projects, programs and policies involve technological and institutional change as well as changes in the human agent, as so many do, it is important to note that there is no automatic ordering of alternative actions, projects, programs and policies which will satisfy the mathematical conditions necessary for locating an optimum, even if a common denominator has been found. Traditional projections have long been used to rank policies, programs and projects according to various criteria in which they should be executed. Computer simulations have similar uses. Again, interaction between investigators and decision makers is important in helping establish the sequence in which different actions should be taken. Until such an order is established or proven unneeded, it is impossible to maximize the difference between good and bad, even if a common denominator is available.

The fourth fundamental difficulty is determining which decision-making rule to use in selecting that project, program or policy to prescribe as best or right. In a static economy, with perfect knowledge, foresight, and the necessary common denominator and second-order conditions, the decision-making rule is simply maximizing the difference between good and bad. The matter becomes much more complicated, however, when knowledge is imperfect on both the normative and non-normative sides, and when serious questions exist about the order in which projects, programs and policies should be executed. One possible decision-making rule is to maximize the present value of the expected future net differences between good and bad. Another decision-making rule is to follow that course of action for which the worst that could happen is better than the worst for any other alternative. Still another decision-making rule for a defined group of decision makers is to vote, with the choice going to the alternative which gets the most votes, over half the votes, over two-thirds of the votes or, possibly, a unanimous vote. Still other decision rules involve chance or lotteries, while others involve the use of force as in dictatorships and war. Because the situation being simulated typically involves imperfect knowledge of both the normative and non-normative and unsolved questions about order, it is seldom initially obvious to either decision makers or investigators which decision-making rule should be employed. Again, traditional projections and computer simulations have advantages. Both traditional and computerized simulation projections can be used to study consequences through time of following alternative decision-making rules and thus provide the basis for interaction between investigators and decision makers to acquire knowledge about the trade-offs between alternative decision-making rules.

Another and fifth difficulty has to do with the availability of kinds of information other than the four kinds considered above. Typically, information to solve a given developmental problem is scarce, and that which exists is in divergent forms including experimental data; time series observations; the judgments of informed and experienced scientists, farmers, politicians, administrators, etc.; casual, isolated observations, etc. Yet the complex nature and the urgency of developmental problems require that available kinds and sources of data be used. Thus, techniques specialized on one or a limited range of kinds and sources of data are often unusable, and the analyst needs to have at his beck and call a wide range of techniques capable of utilizing the kinds and sources of the data which are available.

Still a sixth difficulty involves the theoretical concepts available to use in analyzing the available mix of information and data. Such concepts are needed to understand the origin and nature of the technical, institutional and human changes involved in the alternative projects, programs and policies under consideration and to project their consequences. Thus, the conceptual shortcomings of virtually all disciplines, as well as those of economics, create difficulty for analysts trying to solve complex development problems.

A seventh difficulty inherent in large, complex systems of equations for studying economic development problems is that of obtaining analytical[1/] solutions. As size, complexity and nonlinearity increase, this difficulty and attendant costs increase enormously. Table 3.1, taken from R. G. E. Franks, shows the classification of systems of simultaneous equations and their ease of solution by analytical methods.

For sets of relatively simple, linear equations, analytical solutions can be found even for systems which have a large number of variables, the main limitation being computer size. However, if the equations are nonlinear, as is often the case

TABLE 3.1

Classification of Mathematical Problems and Their Ease of Solution by Analytical Methods [Franks, 1967].

Kind of Equation	Number of Linear Equations			Number of Nonlinear Equations		
	One	Several	Many	One	Several	Many
Algebraic	Trivial	Easy	Possible	Very difficult	Very difficult	Impossible
Ordinary differential	Easy	Difficult	Possible	Very difficult	Impossible	Impossible
Partial differential	Difficult	Essentially impossible	Impossible	Impossible	Impossible	Impossible

1/ *Analytical refers to using the logic of mathematics in contrast to numerical methods that are dependent upon calculation procedures.*

in models of complex development processes, analytical solutions become impossible except in very special cases. For these reasons, analysts have turned to numerical, in lieu of analytical, solutions. This not only facilitates calculations which would otherwise consume much time, but also opens up fields where there are no mathematical ways of finding analytical solutions. Numerical analysis can handle economic systems involving much greater complexity than could normally be handled by conventional mathematical or logical analysis. Methods which are limited to analytical solutions may be less efficient than those not so constrained.

Difficulties With Various Specialized Techniques

Almost all specialized techniques encounter the above seven difficulties in greater or lesser degree. Under certain conditions, each specialized technique is rendered virtually useless. In this section, we examine two specialized techniques which are sometimes used alone and are sometimes incorporated in the general system simulation approach. They are what we term: (1) the equilibrium, simultaneous equations method with statistically estimated coefficients and (2) maximization models such as linear programming (LP) models, which are always used in the maximization mode. The first kind of model can also be used in the maximization mode which is different than noting that the equilibria may be reached as a result of maximizing activities of firms and households. In addition we examine a number of other techniques as a group.

Equilibrium, Simultaneous Equations With Statistically Estimated Coefficients

Sets of equilibrium, simultaneous equations with statistically estimated coefficients are sometimes used for analyzing economic systems and evaluating the impact of alternative economic policies on the behavior of an economic system. They can be used by themselves or incorporated in more general systems along with components based on other techniques. A set of such equations takes the following form (Naylor, 1970):

$$AX_t + BY_t + \sum_{j=1}^{p} B_j Y_{t-j} + CZ_t + D = U_t$$

where:

X_t = an m x 1 vector of exogenous variables

Y_t = an n x 1 vector of endogenous variables

Y_{t-j} = an n x 1 vector of lagged endogenous variables when $j = 1, \ldots, p$

Z_t = a vector (q x 1) of policy instruments or variables

U_t = an n x 1 vector of stochastic disturbance terms

A, B, C, D = coefficient matrices whose parameters can be estimated by various statistical methods from time series data.

The simultaneous equation technique relies heavily on time series data in order to estimate statistically the coefficient matrices of the system. This leads to several difficulties. First, this may preclude the researcher from including certain variables of interest to him in his model simply because the time series data for the variables do not exist. Second, though information about likely values of certain coefficients may be available from knowledgeable experts in the field, the general procedure is so oriented to estimating all of the coefficients from the time series data that such knowledge is ignored or rejected. Although certain computational procedures would allow the researcher to use such knowledge, as a practical matter it may be awkward and difficult to use even if available; this is especially true when nonlinearities are involved.

In order to estimate the coefficient matrices A and B and, in particular, C in a policy context, a range of values for the variables must be present in the data upon which the estimation procedures are applied. If there is little variability in the variable, estimation of its coefficient is difficult if not impossible.[2/] Furthermore, even if there is a sufficient range of values of the policy variables (Z vector) to indicate that lack of variance is not a problem, another difficulty arises which gets to the heart of describing an economic system with linear relationships. When estimating a set of linear simultaneous equations, there are a number of statistical devices which indicate how well the estimated linear system approximates the real system. There are no such devices to indicate how well the linear system approximates the real system if some of the variables are extrapolated beyond the range of the data. It is at this point that the weakness of linear approximation shows. Suppose the policy maker wanted to assess the impact of changing some of the policy variables to values outside the range of previous data. If the system contains nonlinearities, as it probably does, linear extrapolations will become unusable very early in the production period, and it becomes clear that a method which can incorporate the real nonlinear relations would be preferable. Many times information on such nonlinear relations is available.

When such a set of equations is set up with respect to economic phenomena, the equilibrating forces in an economy make some endogenous variables functions of other endogenous variables. These forces are typically conceived to be the result of the maximizing activities of entrepreneurs and consumers in accordance with neoclassical theories of the farm and household. Under the extremely dynamic situations involved when alternative developmental projects, programs and policies are under consideration, it is often doubtful whether entrepreneurs and consumers can carry out the maximizing activities assumed to be providing the equilibrating forces. Even if such assumptions are valid, estimation problems may arise. Sets of structural equations, each involving more than one endogenous variable, are typically converted to a "reduced form" before standard statistical estimation procedures are used to estimate parameters. Conversion to, and reconversion from, reduced forms depend on satisfaction of "rank and order" criteria in the matrices. Failure to meet these criteria weakens the parameter estimates. Analysts are tempted to ignore complex interrelationships in order to avoid "rank and order" difficulties. The result can easily be less reliable parameter estimates than available from alternative kinds and sources of data and information with less sophisticated estimation and approximation techniques.

2/ The variance of the parameter b_i in B or c_i in C is a function of the variance of x_i in X, y_i in Y and z_i in Z, the number of observations, and the intercorrelations among x_i, y_i, and z_i.

Once such a set of equations has been formulated and the parameters have been statistically estimated, the next step is to apply the model to the evaluation of policy alternatives. Naylor (1970) discussed three possible methods for policy evaluation using such models as those of (1) Theil; (2) Tinbergen and (3) policy simulation (specialized, not general).

According to Naylor, Theil's method is to find values of Y_t and Z_t (for the equation considered on page 20) that will maximize a welfare function: $W = f(Y_t, Z_t)$, subject to the specified conditions above and given predicted values of X_t and U_t, with observed values of Y_{t-j}. The difficulty here is that of acquiring the normative knowledge required to specify the welfare function. As the method requires an interpersonally valid common denominator to serve as the welfare function, it is more difficult to use it in interaction with decision makers to acquire the necessary knowledge of the common denominator. More general approaches are capable of postponing use of a common denominator until later in the interactive process.

The Tinbergen method, as explained by Naylor, assumes no knowledge of the social welfare function and thereby avoids the maximization problem. It does, however, assume that policy makers can specify fixed target values for each of the endogenous variables. In effect, it shifts the common denominator difficulty from investigators to policy maker. With fixed target values for Y_t, the next step is to solve the simultaneous equations for the policy variables Z_t given predicted values of X_t and U_t and recorded values of Y_{t-j}. The values of Z_t which provide for the desired levels of Y_t are then said to be consistent with the structure of the economy. The difficulty here is that the fixed targets are themselves tentative solutions to the problems under consideration. Determination of which targets would be best or right to attain involves all forms of the difficulties defined above.

Specifying target values by policy makers outside the set of equations involved is within the realm of reason and empirical possibility and can be done by policy makers in a close, desirable kind of interaction with investigators. However, a mathematical question which arises for Tinbergen's method is whether the system can be solved analytically for the Z vector. If the number of Z variables exceeds the number of Y variables, the number of unknowns will exceed the number of equations, and an infinite number of solutions will be possible. However, when there are more policy variables than equations, q - n of the Z variables can be assigned arbitrary values, and the system of equations solved for the remaining n policy variables becomes a procedure of questionable realism and intellectual honesty when a more forthright appraisal of a situation would simply indicate that there are more unknowns to be estimated than there are equations. This question is in addition to the general questions raised above about systems of simultaneous equations with coefficients statistically estimated for time series data and based on maximizing assumptions concerning firms and households.

An alternative to the Theil and Tinbergen methods is the policy simulation method outlined by Naylor. It has the advantage of not requiring a social welfare function or specific target values for performance variables. Rather, it requires only different sets of feasible policy alternatives and endogenous variables to monitor in order to help policy makers evaluate performance under those alternatives. For a linear model, the values of the endogenous variables including the performance variables at each point in time are given by:

$$Y_t = -B^{-1}AX_t - B^{-1}\sum_{j=1}^{p} B_j Y_{t-j} - B^{-1}CZ_t - B^{-1}D + B^{-1}U_t$$

(where B^{-1} is the inverse of B) given predicted values of X_t and U_t, observed values of Y_{t-j}, and specified values of the policy instruments Z_t in which the analyst or policy maker may be interested. For each set of policy variables, the computer can trace out the time paths of the performance or criterion variables of interest to the policy maker. This output allows him readily to compare the effects of various policies and provides for healthy interactions between policy makers and investigators.

The "policy simulation" method outlined by Naylor appears very similar to the general system simulation approach followed in our research and already briefly described in Chapter I. However, there are some subtle, but important, differences which we hope to clarify in the remainder of this chapter. We feel that the general system simulation approach has greater flexibility than the policy simulation method both in terms of (1) the initial formulation of the model and in the estimation of its coefficients and (2) in application. In his comparison of Naylor's (1970) discussion of his policy simulation method with his discussion of our general system simulation approach, Holland (1970) notes some basic differences:

> "I may be oversimplifying a little but I think it is fairly accurate to say that Professor Naylor represents the econometrician viewing simulation as an extension of his formalized field--an extension that offers new opportunities but which should be exploited with care to maintain the values of a close connection with rigorous statistical theory. The Michigan State trio, on the other side, represent the systems analysts who believe they are making a model of "reality," uninhibited by the inflexibility of the econometrician's standard mathematical forms.
>
> ". . . concerning model formulation, it would seem that Naylor regrets that he cannot keep his models linear, while the Michigan State group goes in freely for exponential lags, branches, and multiplicative variables. It is not that Naylor does not recognize nonlinearity; in fact he says, 'Unfortunately, realistic econometric models are seldom linear, (but he also says), . . . any nonlinear econometric model can be approximated by a linear model . . .' Such linearization is suitable only for small perturbations, whereas in studying development plans and policies, we are concerned with major changes in the variables.
>
> "As for the Michigan State group's approach to model formulation, I'm sure it must make a good econometrician (like Professor Naylor) shudder to read, 'Modernization proceeds at a rate directly related to the level of profitability for the producer. This component also includes an innovation diffusion mechanism which allows for spontaneous (farmer to farmer) diffusion of modern techniques occurring over time, if necessary inputs, information requirements, etc. are available.' Imagine trying to verify that relation and estimate its parameters! But the defense of such *a priori* formulation is hard to overcome. If experienced observers believe that this is the way things really work, that is the way they should be in the model, even if the parameters cannot be measured."

We would feel better had Holland replaced "measured" in the last line with "estimated by standard statistical techniques from time series and cross sectional data, but have to be obtained instead from a wide variety of kinds and sources of information and methods of estimation, approximation, judgments and guesstimations."

However, the Naylor method has the advantage of permitting interaction with decision makers as a means of developing and expanding normative knowledge, settling questions about optimum sequences, and determining appropriate decision rules. We find this advantage extremely important. We and Naylor seem drawn to simulation analysis because it provides a better interface between the statistically rigorous models for estimating matrix coefficients and the way decision makers consider policy alternatives than do the Theil and Tinbergen approaches. However, we are also concerned with interfaces with a wide variety of other estimation and approximation techniques and sources of data.

As to application, the necessity to invert matrices for each period of time considered greatly increases calculation costs for simultaneous equilibrium equations of the type dealt with by Naylor as compared with more general approaches which do not always require matrix inversions.

Linear and Nonlinear Programming Models

While linear and nonlinear programming models (LP and NLP) can be classed as sets of simultaneous equations, they differ from those just considered in two important respects: (1) their coefficients are obtained from a wide variety of kinds and sources of information with a wide variety of estimating and approximating techniques as contrasted to being specialized on time series data and probability estimation and (2) they are always used in a maximizing (or minimizing) mode. The second characteristic requires that the fundamental difficulties with respect to an interpersonally valid common denominator, order and decision rule be resolved before the set of equations is used. This requirement makes it difficult to use LP and NLP to resolve such difficulties, though their resolution may be the most important aspect of solving the development problem under consideration. While LP and, to a lesser extent, NLP are powerful techniques where applicable, premature (i.e., prior to resolving the four difficulties discussed above) application produces misleading and inappropriate "solutions" to developmental problems. Carefully used, LP and NLP may provide useful components for more generalized approaches or even the entire basis for solutions to developmental problems. Run recursively and parametrically, LP and NLP analyses can trace out time sequences for alternatives. These time sequences or projections can be used in interaction with decision makers to reach maximizing decisions precluded from the LP analysis even though the LP analyses were constrained by the maximization or minimization requirement of the technique.

Two other important disadvantages of LP and NLP programs are: (1) the fact that the entire system, or large components of it, must be constructed before testing can be carried out on the computer in the maximization mode and (2) the expense and time involved in inverting large matrices. The first of these disadvantages makes it difficult and costly to "debug" an LP or NLP, while the second often limits sensitivity and Monte Carlo analyses of LP and NLP models.

Other Specialized Techniques

There is another group of techniques to be discussed en masse. This group includes cost/benefit ratios, internal rates of return, net present value analysis, etc. which are used more often for project and program than for policy analysis. The general characteristic of these methods is that they require prior resolution of part or all of the fundamental difficulties involving interpersonally valid common denominators, order and decision rules. As such they are of less use than a more general approach as a basis for interacting with decision makers to resolve such difficulties. Further, they raise the temptation to make premature application before these difficulties are resolved. One of the typical difficulties considered above arises when attempts are made to express the loss and attainment of nonmonetary values in monetary terms in order to compute cost/benefit ratios, internal rates of return and net present values. Often the unrealism of such attempts introduces credibility gaps and tensions between investigators and decision makers, which preclude the interaction necessary to resolve difficulties with the common denominator and its interpersonal validity.

A General System Simulation Approach

We view the general system simulation approach as a flexible, iterative problem-investigating process that includes problem formulation, mathematical modeling, testing and refinement of the model and problem solution in close consultation with decision makers. We view it as flexible with respect to (1) types and sources of data, (2) estimation and approximation procedures and (3) techniques. Therefore, we use the adjective "general" to describe this approach. All specialized techniques are regarded as potential contributors to our approach if, when and as appropriate. Included are: LP, NLP, equilibrium simultaneous equations with parameters estimated statistically from time series data; input/output table analyses; cost/benefit, internal rate of returns and net present value analyses; other techniques such as program planning and budgeting (PPB) and project evaluation and review techniques (PERT) and still other unnamed techniques. The approach is a process involving creative design of alternative courses of action to help provide solutions to the development problems at policy, program and project levels. These problems and alternatives partially determine the model structure and level of aggregation. The process can be conceptualized diagrammatically as shown in Figure 3.1. As the arrows indicate, the general procedure is from problem definition to model application, including interaction with decision makers, and problem solution. But the reverse arrows indicate that the process is iterative or "learning" in nature. Prior stages are often repeated on the basis of information acquired during a subsequent stage; that is, the approach explicitly recognizes the feedback nature of the problem investigation procedure and can accommodate the learning and knowledge accumulation likely to take place at any stage in the process. The flexibility of this approach allows for (1) sequential changes in model structure, parameters and objectives, leading to better models with a broader range of outputs and (2) utilization of any appropriate technique. The "output" of a simulation is a set of system performance variables associated with each set of policies and/or development strategies indicating the attainment of various benefits and the incurrence of various damages at different points in time from alternative policies, programs and projects. These estimates can be compared through interaction with policy makers for different alternatives in choosing the alternative which best solves the problem under consideration. Again, this interaction may lead to feedbacks and modification of the model.

While this sequence of steps can be followed in using specialized techniques for solving real-world problems, we feel that the general system simulation approach has a flexibility advantage which particularly suits it to this iterative process; i.e., because it can use any specialized technique as appropriate and because it can use information of any kind and source, it has the strengths of all techniques available but can reject any on the basis of its disadvantages.

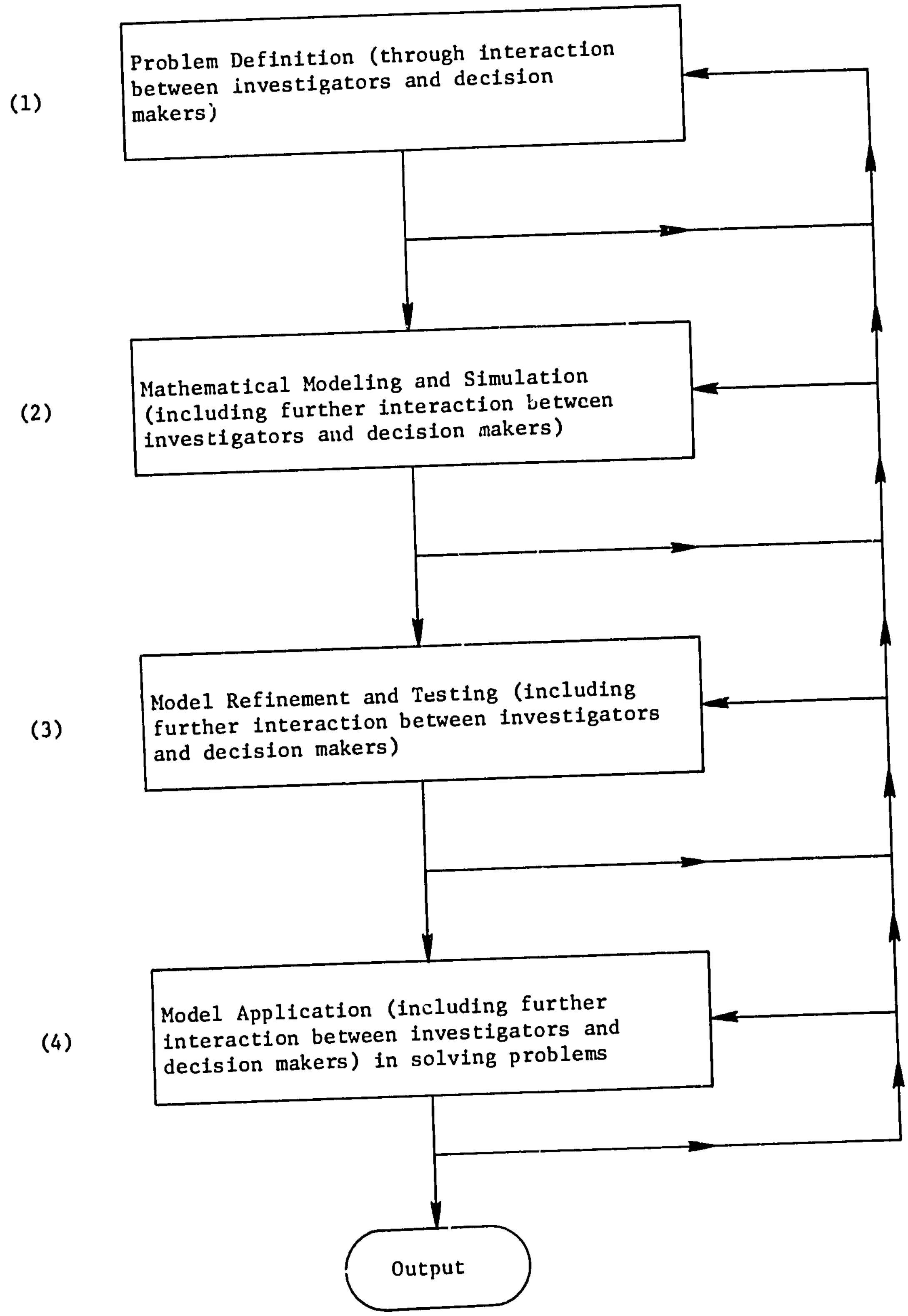


Figure 3.1. Computer simulation as an iterative problem investigating process.

Problem Definition

Problems are identified by the gap between the value of what is and the value of what is or might be made possible. Many of the values involved concern human well-being (Seers, 1969). "Well-being" is reflected in levels of nutrition, employment, the level and distribution of per capita incomes, etc. Other indicators of well-being are levels of education, freedom of action, independence of political determination, freedom from dictatorial government, repressive codes, noise and pollution.

Helping solve the practical problems of development requires both normative and non-normative knowledge. The lack of such knowledge, both descriptive and analytical, places one of the major limits on reaching prescriptions of practical worth concerning change in social institutions, technological instruments and the human agent. Lack of knowledge concerning both the normative and non-normative limits the definition of the problem in the first place and may lead to the investigation of irrelevant questions and the prescription of unacceptable solutions. An early step in problem formulation is recognition of what values and positive knowledge are relevant to the development problem under study.

The variables used to measure the performance of the system are normative. On the non-normative side, physical and social theories are needed to understand the functions and mechanisms of the system under study. Changes in technology, institutions and human beings are made explicit by proposing and modeling alternative means of achieving improvements in the performance variables. Thus, an objective of the initial problem formulation phase is to specify: the functions and mechanisms of the system, appropriate measures of system performance or values and the available means for achieving "goods" and avoiding "bads." In short, the intent is to identify the major questions which will be put to the systems model after it is formulated. During the course of problem definition and subsequent stages of model formulation and application, improvements are made in both the normative and non-normative information which contribute to the model and, hence, to the entire problem-solving process.

In a large-scale system study, effective problem definition requires creative interaction among decision makers, planners, systems analysts and other specialists. The multidisciplinary research team at Michigan State University was fortunate in having available professionals with a wealth of experience in the Nigerian agricultural economy. The Consortium for the Study of Nigerian Rural Development (CSNRD), headquartered at Michigan State University, provided a substantial backlog of information about the country and served as a center for contacts with people in the U.S. and Nigeria who were knowledgeable about African agricultural and industrial development (CSNRD 33). Further, the CSNRD collaborations with AID, FAO and Nigerian planners and policy makers provided a fairly clear picture of the current governmental and planning institutions related to the agricultural economy and to the means by which they influence the economy. This helped in determining the planning clientele for whom the model should be built. As a consequence, the major policy questions and the corresponding relevant sectors, interrelationships and variables in the Nigerian economy were isolated more easily than they might have been.

The following are examples of questions the model is designed to answer. They are only illustrative of what can be done; many other questions could be posed through interaction between systems researchers and Nigerian decision makers.

However, these questions illustrate the policy level at which we aimed and help to describe the level of aggregation toward which the simulation model is oriented.3/

What would be the impact on farm and nonfarm income (total and per capita), per capita nutrition, export earnings and export-import balances, level of demand for farm and nonfarm products, levels of employment, government tax revenues and expenditures of:4/

1. increasing market board prices paid to export crop producers, i.e., reducing the spread between world and domestic prices?
2. increasing production research and extension efforts on export crops?
3. increasing research on food crop varieties and production practices, and subsequently funding production campaigns to implement the most promising findings?
4. stimulating private investment or making public investments in agricultural input industries, storage and processing facilities, and required supporting infrastructure improvements?
5. stimulating private and public investments in nonagricultural sectors of the economy?
6. instigating human population-control programs?
7. promoting import substitution in various sectors of the economy to provide for greater backward linkages in the economy?
8. changing the distribution of income between rural and nonrural people and/or from relatively higher incomes to lower income people?4/

These are general questions encountered in many less-developed countries. The production of models to answer such questions was consistent with our contractual obligation to develop the system simulation approach. It should be stressed that the development of a model immediately applicable to Nigeria was not an objective of the project or a contractual obligation of MSU to AID.

Specification of relevant policy-making clientele and their most important questions determined which sectors and/or interrelationships needed particular attention within the model and the level of aggregation at which to work. The major sectors and flows as presently conceptualized within the simulation model of the Nigerian economy are shown in Figure 3.2. As seen from the diagram, our

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3/ The Nigerian model can be differentiated from the simulation models built by Holland (1966) for the Indian and Venezuelan economies and Kresge's model (1967) of the Pakistan economy by its adaptability to questions which require either very macro or intermediate levels of aggregation in contrast to the macro specialization of the Holland and Kresge models.

4/ No.'s 5 to 8 are not as explicitly considered for this report as 1 to 4 although with minor modifications of the model they could be considered at a later time.

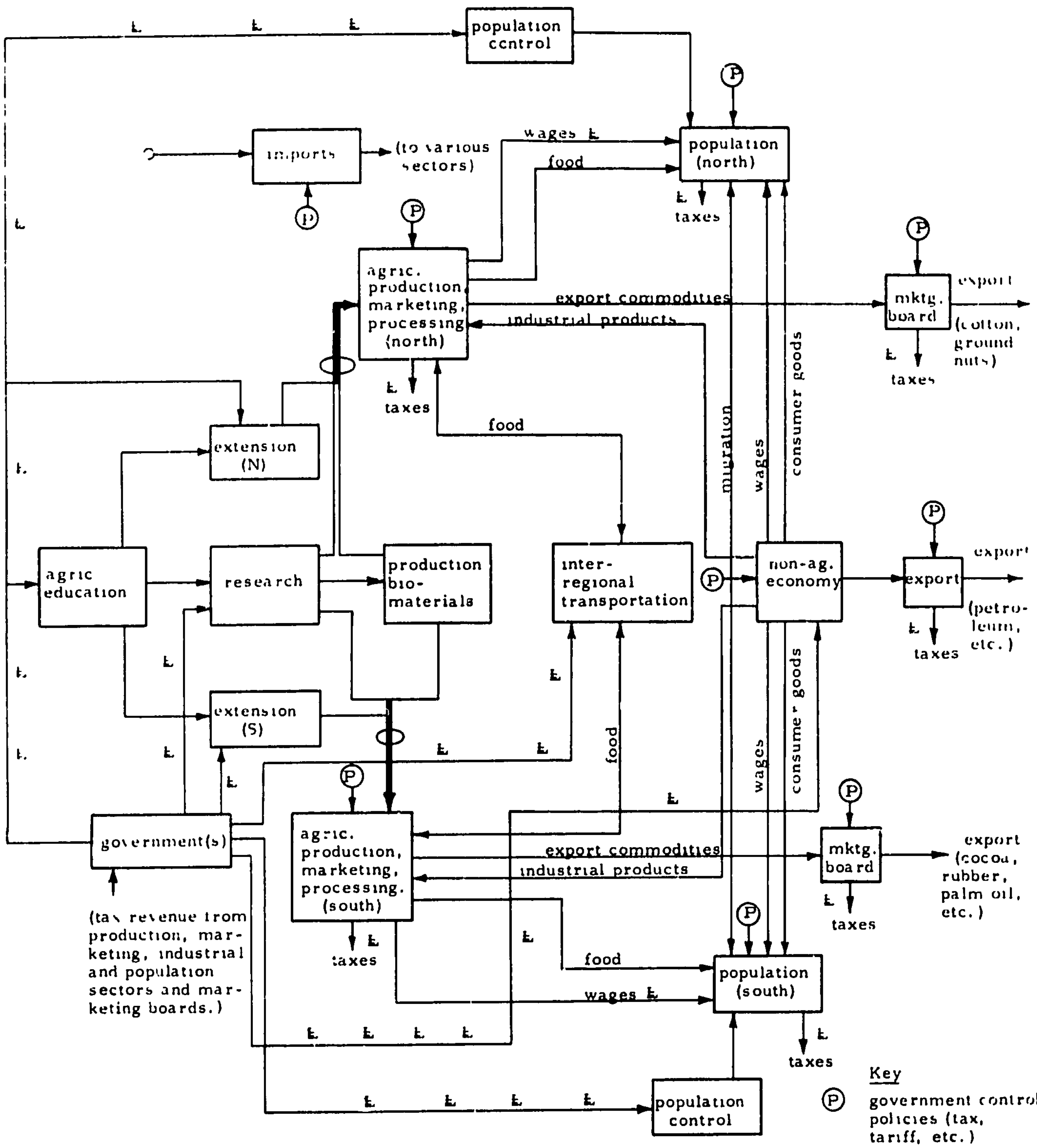

Figure 3.2. Major sectors and flows of a simulation model of the Nigerian economy.

emphasis is on the agricultural sector. Since agriculture contains most of the productive resources in Nigeria (contributing 65 percent of the GDP and 66 percent of Nigerian exports in 1962-63) and in most less-developed countries, its role in future growth will be very important.

Many planners in less-developed countries are concerned with evaluating alternative policies affecting regional specialization of production and trade. These typically involve likely farmer responses to various economic incentives or government assistance projects, etc. Consequently, the model has a commodity orientation, emphasizing export crops. To simplify the consideration of questions related to regional specialization and interregional trade, a two-region (North and South) model was conceived. However, several ecological zones within each region are also differentiated to decentralize the model to a level at which many important policy decisions are being made. While the model is based on Nigerian experiences, the commodity-ecological zone-regional orientation makes the model applicable to a broad range of countries in accordance with the objectives of the AID contract under which the work was done.

Although this diagram shows the main components, sectors and flows to be incorporated into the simulation model, it does not show the basic political decision mechanisms and their points of impact on the agricultural development and adjustment process. In Figure 3.3, the relationship between specific policy variables and the components incorporating the main streams of economic activity are shown. These range from input allocation decisions to production results, following through the marketing process to consumption. The flows of material, money, price information and regulator activities are shown. Thus, this general mechanism applies to virtually any commodity produced. Specifically, it applies to staple food crops, cash crops, livestock and the export crops (oil palm, groundnuts, cotton, cocoa and rubber) in the agricultural production and marketing sector of the model.

Mathematical Modeling and Simulation

Conceptually, a simulation model of an economic system can be viewed in the following general mathematical form:

$$\psi(t+1) = F[\psi(t), \alpha(t), \beta(t), \gamma(t)]$$

<u>where</u>:

$\psi(t)$ = a vector (set of variables) which defines the state of the <u>simulated</u> system at any given time. State variables usually involve the level of a variable at a given time and might be such things as production capacities, land allocated to various activities, prices, population by subgroups, levels of technology, etc.

$\alpha(t)$ = a set of parameters that defines the structure of the system. Structural parameters usually involve rates of change of variables between levels, or input-output coefficients. For example, technical coefficients, response coefficients, price elasticities, migration rates, birth and death rates, etc. (Some of these may be subject to variation within the model.)

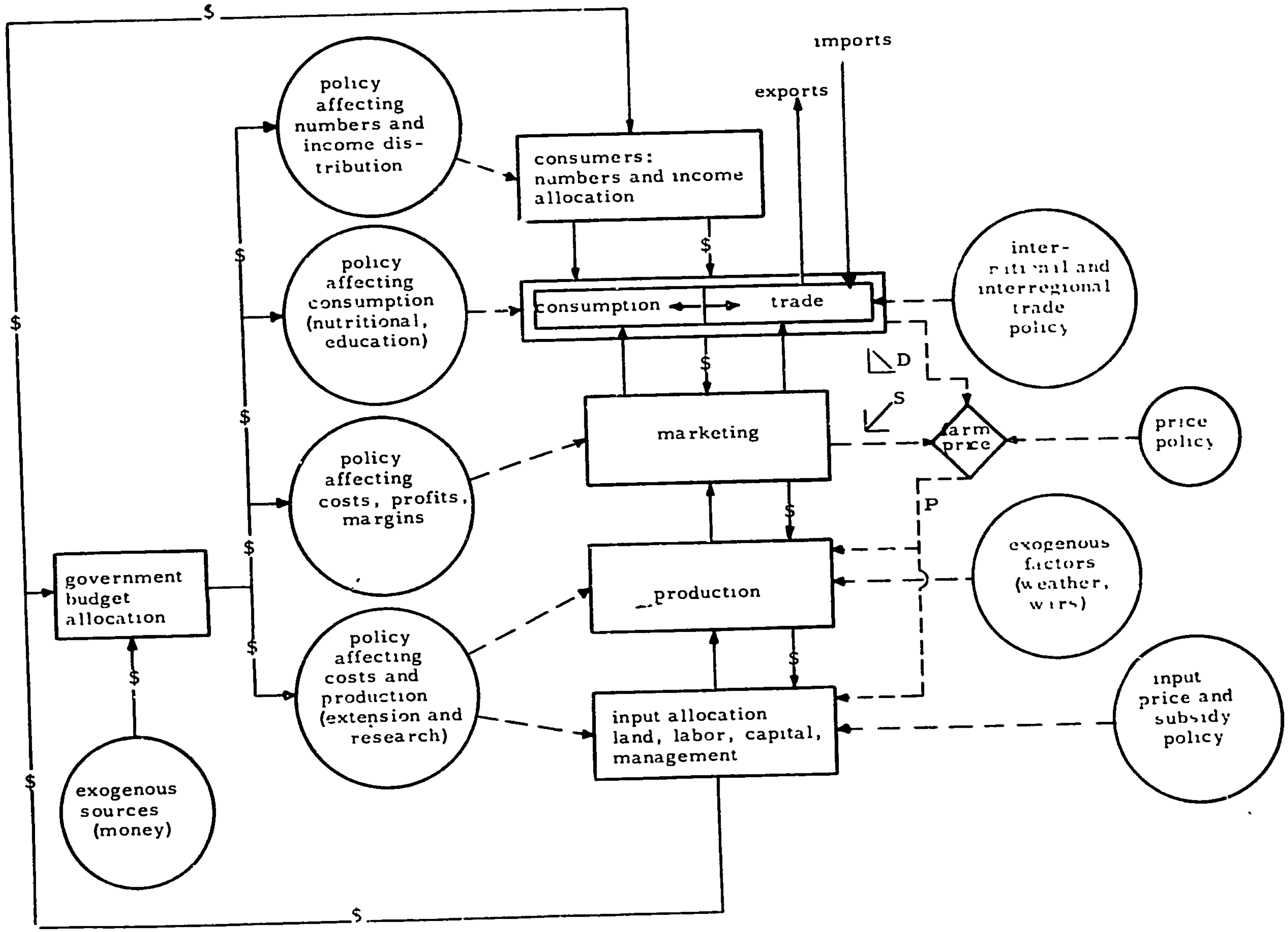

Figure 3.3 Basic components of development model with main material, money, price, and regulation (information) flows.

$\beta(t)$ = a set of exogenous variables that influence system behavior; e.g., world prices, weather, etc.

$\gamma(t)$ = a set of variables which can be controlled to alter the system's performance in various directions; e.g., investment alternatives, tax policies, import duties, production campaigns, etc.

This equation illustrates how the variables which define the state of the simulated system in time period t + 1 is a function of the state of the system and the values of the parameters (α), the exogenous variables (β) and the policy variables (γ) at time period t. This is a general representation of the difference equation formulation of the system model which describes the state of the system and subsequent performance at discrete points in time. The difference equation formulation of the state variables is particularly amenable to digital computer calculation; e.g., knowing the values of variables and parameters at point t in time allows the calculation of the state variables at time t + 1. Long chains of equations link time period to time period and, within time periods, link processes to processes. If equilibrating components are used, they are simple and are regarded as a step in a process. And if the chains of equations, in turn, feed accounting routines, the total system can be modeled without costly matrix inversions. Though there are important computational advantages in avoiding matrix inversions, it should be emphasized that the mathematical form of these equations is virtually unrestricted and that matrices can and should be used whenever these advantages outweigh their costs. The abstract model, based on observations and theories, is designed to behave as much like the real world as feasible; therefore, dynamic interactions, nonlinearities, discontinuities, logical branching relationships, time delays, and irreversibilities and matrices can be embodied in the model. The linear models discussed earlier in this chapter are special cases of this general formulation.

A second equation is used to measure how well the simulated variables ($\psi(t)$) correspond to real-world data ($\psi_w(t)$):

$$\theta(t) = H[\psi(t), \psi_w(t)]$$

<u>where</u>:

$\theta(t)$ = a set of intermediate output variables which measure how well the model of the system $\psi(t)$ corresponds to reality $\psi_w(t)$; e.g., residual sum-of-squares, R^2, plots of observable data and simulated data, etc.

ψ_w = a vector of variables which describes the state of the system in the real world. (These may be the same variables as in ψ, but are observed values rather than simulated values. More than likely ψ_w is a smaller set than ψ.)

Thus, $\theta(t)$ might be a measure of total sum-of-squared deviations between the real and simulated values of state variables such as the level of production of a cash crop. Of course, other measures could also be defined. The measures of goodness-of-fit would be applicable in the refinement and testing stages of the simulation process.

A third equation is a general representation of those equations which indicate how much of which "goods" are attained and "bads" are incurred at different points in time:

$$.t) = G[\psi(t), \alpha(t), \beta(t), \gamma(t)]$$

<u>where</u>:

$\pi(t)$ = a set of output variables which measure the system's simulated attainment of various "goods" and avoidance of various "bads," e.g., profit, income rates of growth, per capita income, foreign exchange earnings, governmental expenditures, unemployment, etc.

It also indicates that these performance or criteria variables are functions of the state variables (ψ), parameters (α), exogenous variables (β) and the set of policy variables (γ). The criteria variables would include, among many others, such simulated outputs as incomes, rates of growth and GDP. These output variables are relevant in the model application phase where the performance of the system is simulated over time under various policy alternatives, and prescriptions are made as to the "right" action, project, program or policy to implement.

This general formulation is exemplified in the hundreds of parameters and structural relationships actually incorporated in the model. However, to formulate the model specifically requires: (1) precise description of the model components, structures and mechanisms; (2) explicit algebraic equations to describe the structures and mechanisms within components, and (3) programming for computer simulation.

Description of model components is usually aided by diagramming the system as shown in Figure 3.2. The structure and some of the mechanisms can be shown in the component diagram; however, usually more detailed modeling is necessary than block diagrams.

These building blocks are composed of interrelated functional relationships which can be broken into more manageable components because of their recursive nature, (i.e., one function necessarily follows another in time and is dependent upon the output of the previous function) or their seeming independence (geographic, behavioral) at any one point in time. By specifying the linkages between components (an output from one either being an input to another or a performance variable), the research team can detail the functional relationships within each component and proceed to estimate the relevant coefficients. In this way, research efforts can be effectively decentralized within the coordinated and centralized, but tentative, format initially determined. Later, as model changes and experimentation require, any individual component of the model structure can be more easily isolated and changed than in many more specialized approaches. We deem the modular design of system simulation models to be an extremely important feature of the general system simulation approach--one that contributes greatly to its great flexibility. The notion of breaking a large-scale system up into its component parts is a major contribution from the systems science discipline.

In order to specify the mechanisms of the model for programming the computer simulation version, the entire model must be written in mathematical form. This can be accomplished in several ways. The systems analyst can write out the equations of the model, using variable names compatible with the programming language, and the computer programmer fills in the computer logic to make the model operational on the computer and consistent with the structure of the model. At other times, the systems analyst may be able to provide the programmer with a detailed flow diagram and initial equations of the mechanisms to help him make the translation into computer language.

The modeling process is not the static, mechanistic procedure it may appear to be. A good deal of trial and error is necessary, based upon descriptive information, the theoretical conception of the system, its components and interactions to prepare even a "first attempt" of a programmed model. As such, a model of an economic system is based upon the analyst's theoretical, institutional and empirical understanding of the economy. Assumptions may also be incorporated into the model to specify the technological, behavioral, cultural and institutional constraints and interrelationships that might be affected by the policy maker.

While there are dangers in premature use of maximization and equilibrium models, the system simulation approach is general and flexible enough to incorporate maximization or statistically estimated equilibrium models where appropriate. In fact, such components could constitute the whole of a computer simulation exclusively concerned with a maximization or based upon econometric estimates of historical behavior (Kellogg, 1971). The model clarifies the assumptions about the behavior of the components. Because the simulation process is iterative, the selection of the assumptions (which may be only one set from a number of possible sets of assumptions) may be modified, based upon subsequent comparisons of the model's behavior with reality.

In building a model of an economic system we must: (1) specify the structural interrelationships; (2) determine the important instrumental (policy) variables; (3) determine the directions of causation; (4) specify functional forms of the technological or behavioral relationships that seem to fit the current and potential situations envisioned, and (5) tentatively specify the parameters and shapes of the functional relations. The consistency of the various structural relationships and parameter values can be checked by computer simulation. Conceptual and programming errors can often be detected during the first few runs of the model on the computer. Refinement and testing of the model would follow.

Model Refinement and Testing

An empirical truth which seems to apply to the development of simulation models is that a model does not work well the first time it is used. The refinement and testing of a simulation model is an iterative procedure within the overall iterative methodology of simulation. Computer runs are made for the purpose of detecting errors. Whether these are programming errors or errors in parameters or structure, the procedure is to run the model and check the output for inconsistencies. Checks are made against (1) theoretical concepts, (2) dynamic systems concepts, (3) historical time paths of variables and (4) prediction of future time paths.

Output variables that do not behave according to theoretical concepts may indicate errors in the parameters or in the structure of the model. For example, an obvious error would exist if there were, for a technical process, a greater quantity of output than input, i.e., a process showing greater than 100 percent efficiency. The behavior of variables in the output of computer runs of the model must also behave according to dynamic systems concepts. For example, if we know from observation that the system under study is dynamically stable, a model with variables showing unstable behavior over time would not be acceptable. Or if certain output variables grow or decline at rates inconceivable for the economic system, the model would need further refinement.

The third check for inconsistencies is made with historical data. In underdeveloped countries, there may be insufficient data to make historical comparisons for all variables. However, for certain important output variables, time series may be available. The desired correspondence of the model output to the historical record may vary according to the situation. Various goodness-of-fit tests can be made which indicate when gross inconsistencies are detected (Naylor and Finger, 1967). But from a statistical standpoint the only conclusion that can be made, if the goodness-of-fit tests are positive, is that the model is not inconsistent with the historical record. Consistency does not indicate that the model is true or valid in an empirical sense. In this sense, the hypotheses incorporated in the model can be rejected but never confirmed as "true." However, when the historical record does not reject the model, we can have greater confidence in the validity of the model. The preceding statements apply to all models, not just simulation models.

A fourth way of checking for inconsistencies in a simulation model is by predicting the path of certain output variables which can be monitored in the real system. If the variable cannot be monitored or observed in the real system except at excessive cost, checking predictions may not be feasible. An example from the Nigerian model may make this clear. One of the important variables in the model in determining cocoa output is the acreage and age distribution of trees in the population. It would be costly to obtain a sample of the cocoa tree population in Nigeria, but statistics on the total production of cocoa are available because a marketing board buys almost all that is produced. Thus, a model that uses rough estimates of acreage and age distribution could be refined and tested against predictions of total cocoa production, rather than making a costly survey of acreages and age distributions.

It would be impossible to predict every output variable in a model and then check for inconsistencies against the output of a real system because of the excessive costs involved. However, a model should have some simple output variables that "in principle" can be checked against the real system. Whether or not these variables are checked depends upon the cost of monitoring the real system and the importance attached to prediction accuracy in applying the model. Discussions with the decision maker will help to determine the importance of predictions in the actual application of the model.

Model Applications and Problem Solutions

The most important reason for developing a simulation model is to provide an approach (a laboratory) for exploring the consequences of a wide range of alternative plans or management strategies. In this iterative process, there should be close interaction among decision makers, systems analysts and computer specialists. One simulation experiment can lead to the creative design of a new and better one which may involve reprogramming or even basic modifications in the model. The objective of this type of simulation experiment is to unfold a set of development strategies that are not inconsistent, are mutually reinforcing and show how resources could be more effectively used to solve the basic problem.

Application of a simulation model involves two interrelated phases: (1) sensitivity tests and (2) interaction with decision makers.

Sensitivity tests are repeated runs of the model on the computer with different assumptions made about parameters in the model. A model at this stage of development, following the refinement and testing phase discussed above, usually contains the "best" available estimates for many of the parameters. Sensitivity runs test the impact of possible errors in these parameters on model outputs. These tests will help the researcher determine which parameters cannot be accurately estimated with existing data, and where additional secondary or primary data may be required for a more accurate estimate of the sensitive parameters. A second objective is to ascertain possible parameters which may have a large impact on output variables. These sensitive parameters may be likely candidates for possible policy or program manipulation by the decision maker or policy maker. Knowing which parameters are sensitive to policy manipulation is an aid in communicating with the policy maker and facilitating the design of useful experiments to answer policy questions in subsequent runs. Another useful output is determining whether variability in nonpolicy parameters will mask or cancel the impact of policy or program parameters. It may be impossible to change policy variables sufficiently to alter the outcome (mean and variance) of the system. Such results are important to policy makers in helping them avoid adopting policies which variation in other variables may doom to failure.

Following these sensitivity runs and data-gathering activities, actual application can involve designing new policy alternatives for experimentation.

There is no substitute for interaction with the policy maker at this point. If meaningful alternatives are going to be designed for study and experimentation, interaction must take place. If the decision makers exercise their ingenuity and creativity in designing new alternatives, a highly advantageous, creative and original interaction can take place. The interaction can take many different forms, but its objectives are to: (1) communicate the structure of the model to the decision maker; (2) determine whether the model is an adequate approximation of his conception of the way the "real" system operates and perhaps sharpen that conception, and (3) design new and meaningful policy alternatives to be tested experimentally on the computer.

The model and its simulated results do not make decisions for the policy maker. Ideally, the model is an extension of the decision-making capacity, providing information on consequences of various policy alternatives under varying conditions of the system. It can also provide probability estimates of various outcomes, provided that probability distributions of model coefficients are used as input, and the model is built to simulate the frequency distributions of the outcomes. From a decision-making standpoint, the model with its simulated results can provide probability distributions of outcomes of various alternatives under specified conditions.

At this point, it seems worthwhile to reiterate and expand comments made earlier in this chapter concerning the role of interaction between researchers and decision makers. In discussing the common denominator, order and decision rule problems encountered in investigating developmental problems, it was pointed out that interaction between decision makers and investigators results in acquisition of normative knowledge that may partially or completely solve the common denominator problem. It was also pointed out that such interaction is a way of solving the problem of program and policy sequencing and selection. Similarly, interactions between investigators and decision makers result in the acquisition of both normative and non-normative information about the consequences of using different decision-making rules. With respect to all three problems, creativity and originality are important aspects of this interaction process.

Concerning both the common denominator and the decision-making problem, normative information is acquired in the interaction between investigators and decision makers. The question now arises as to whether such normative information can be regarded as objectively true. The process of verifying a model involves logical internal consistency, consistency with data on the real world (both historical and current) and, by implication, clarity. A model containing inconsistencies of a logical nature or one which generates data contrary to historical and current experience is not acceptable. The third criterion for verification--clarity--was implied. Obviously, a simulation model is not acceptable until it can be explained in clear, understandable terms and is interpersonally transmissible. A fourth criterion is that of workability. The acceptability or objective truth of a simulation model or component is determined by these four criteria. Both the normative and non-normative (or positive) knowledge acquired in the interaction between investigators and decision makers passes these same tests of internal consistency, consistency with historical and past experience, clarity and workability. It is in the passing of these tests that information is accumulated. Each time a parameter estimate, system component, or simulated result passes the test of consistency with data about the real world, additional "degrees of freedom" are added to knowledge. And, each time such a test is flunked, the resultant reorganization of the simulation model is based on the knowledge "contained in the data" and is a contribution to our organized store of knowledge. Included in the accumulated knowledge is normative knowledge about both orders and consequences of using different alternative decision rules, i.e., simulation and interactions between simulators and decision makers lead to better (1) rankings of alternatives in the order of their decreasing net advance per unit of sacrificed good, and (2) comprehension of the sequences of goods and bads associated with different decision rules. It must be stressed that both the non-normative and normative aspects of the model are, like all knowledge, tentative and subject to revision and correction. Further, it may not be feasible to bring a model to an acceptable level of refinement (despite substantial interaction with decision makers) with fully satisfactory non-normative and normative dimensions and policy prescriptions.

CHAPTER IV

The Northern Region Model: Cattle and Annual Crops

THE AGRICULTURAL ECONOMY OF NIGERIA was viewed, for purposes of simulation, as two major interacting agricultural regions--the Southern tree and root crop economy and the Northern annual crop and cattle economy. (See Figure 3.2 in Chapter III.) This chapter broadly outlines the model components which make up the Northern regional model and presents some results of simulation runs.

The major components of the cattle and annual crop model are: (1) cattle production; (2) land, labor, allocation-annuals; (3) agricultural production and marketing-annuals; (4) market; (5) modernization-annuals, and (6) consumption and budgeting. Other operating routines of the computer program which link the various components together and facilitate the exploration of various policy options are: (1) overall executive; (2) modernization executive, and (3) output-North.

In the sections to follow, the structure and functions of the major components are discussed. Finally, some results from computer simulation runs illustrate the sensitivity tests and validity checks performed on the regional model prior to the merger with the other regional and nonagricultural models into the model of the total economy. An appendix to the chapter presents specific equations that represent the major functional relationships of each component.

General Description of the Northern Regional Model

The current model views northern Nigeria (the old Northern Region) as being made up of the four distinct cropping subregions (See Figure 2.4, page 13.) The subregions are defined on the basis of current cropping patterns which, in turn, reflect differing climatic and soil patterns throughout northern Nigeria. Region 1 includes that land area uniquely suitable for the production of groundnuts and food crops, mainly grains, such as millet and sorghum. Similarly, Region 2 defines a cotton-food zone and Region 3 the region in which groundnuts and cotton compete with each other and with food grains for land use. Region 4 defines an area, largely in what has been called the Middle Belt of Nigeria, where groundnuts and cotton cannot be grown effectively. This region can, however, produce various food crops (mainly roots such as yams and cassava) which may allow future regional specialization in export crops in other areas in Nigeria.1/ A fifth area which overlaps the other subregions and includes the remaining noncrop land is the grazing residual utilized by the cattle herd of northern Nigeria.

The overall organization of the Northern model is shown in Figure 4.1. As shown, the production activities of the model are beef, groundnuts, cotton, food

1/ *A particularly interesting question arises with respect to the impact of low-priced Middle Belt food upon the ability of the southern region to expand export crops such as palm, rubber and cocoa.*

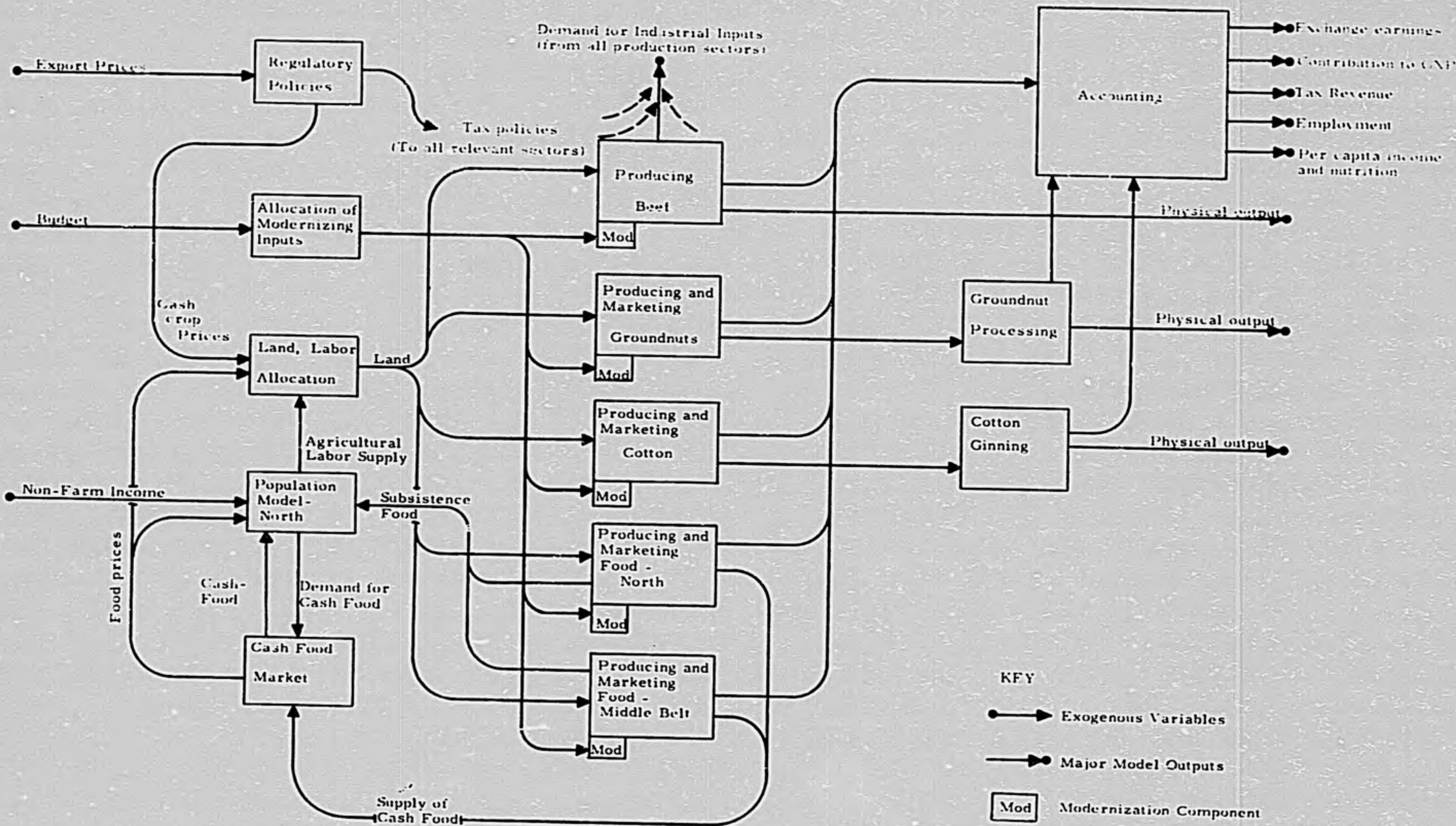

Figure 4.1. Major sectors and interactions of the northern Nigerian agricultural model.

(mainly grains) produced in competition with groundnuts and cotton and food (mainly roots) produced in areas where groundnuts and cotton are not effective competitors for productive resources. The major outputs of the model are physical quantities of the various production activities and other measures of system performance including contributions to Gross Domestic Product (GDP) and Gross National Product (GNP), tax revenue generated, employment, foreign exchange earnings, per capita income and nutrition levels and demand for industrial goods.

To facilitate studying the likely impact of alternative development strategies upon these outputs, the model incorporates major policy variables which can be experimentally varied. The development strategies include allocation of resources to modernization programs for the five production activities, adjustment of marketing board producer prices for groundnuts and cotton, and tax policies. The individual model components will be described separately. Taken together, they constitute the overall Northern regional model.

Cattle Production Component

The cattle industry of Nigeria is largely centered in the tsetse fly-free region of northern Nigeria (Ferguson, 1967; Helleiner, 1966; UNFAO, 1966; Werhahn, et al., 1964). During the wet season (May to October), approximately eight million cattle (managed dominantly by nomadic Fulani), graze on the forage. During the dry season, herds migrate southward in search of water and forage as the habitat of the fly simultaneously recedes southward. A major problem of the industry is lack of adequate dry-season nutrition, resulting in substantial weight losses, lower calving rates, higher death rates and "delayed" animal maturation. Some traditional management practices seem to aggravate this problem by allocating substantial portions of these limited nutritive resources to relatively unproductive animals, perhaps because cattle are often viewed as a store of wealth rather than a strictly productive enterprise. Some observers believe that overgrazing of the limited tsetse-free grassland is causing deterioration of perennial grasses and further aggravating the nutrition problem. Most animals produced in northern Nigeria are marketed in the South. Approximately half of those marketed are trekked hundreds of miles and arrive at consumption centers in very poor condition after substantial weight loss.

In the cattle production component (see Figure 4.2), the livestock population of northern Nigeria is disaggregated into two populations--one traditional and one managed using modern techniques. The traditional cattle population (belonging to nomadic Fulanis), is assumed to subsist on the tsetse-free grazing land of northern Nigeria during the wet season. During the dry season, crop residues and additional grazing land (which becomes available as the habitat of the fly recedes southward during dry months) also add to the nutrient supply. Grazing land and, hence, total digestible nutrients (TDN) for the traditional population are endogenous model variables related:(1) to any food crop acreage expansion required to feed a growing human population; (2) to expansion of cash and animal feed crop acreages, and (3) increased tsetse-free grazing land areas as a result of fly eradication and grazing reserve programs. Expenditures for fly eradication and grazing reserve programs are policy variables which can be varied during model tests.

The "condition" of the traditional grazing land, which influences grass yields per acre, is computed as a function of the number of animals grazing on an area relative to an equilibrium number. Male and female livestock populations and sales are computed as functions of calving rates, death rates and marketing strategies,

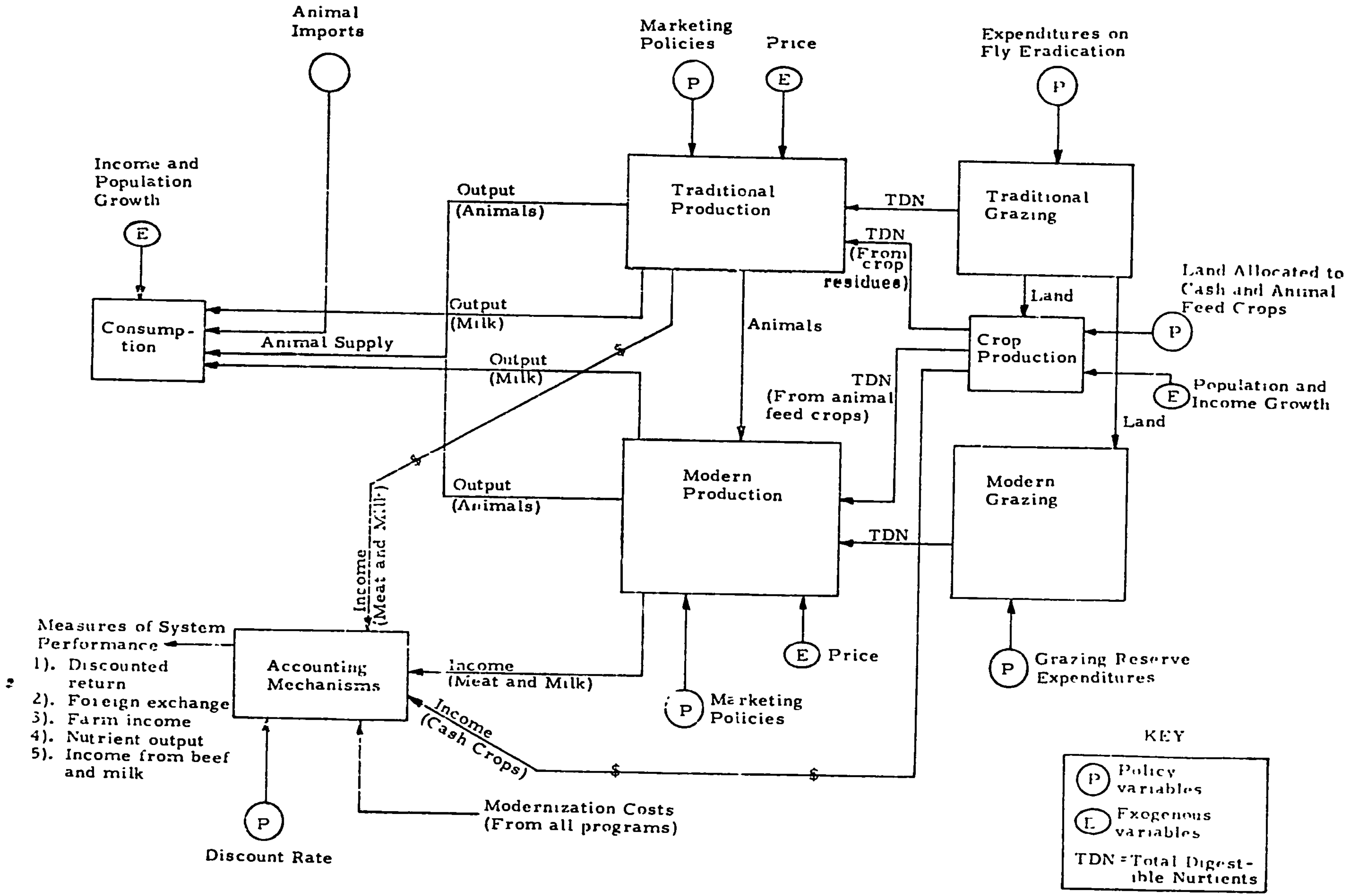

Figure 4.2. A functional flow diagram of cattle production component.

the latter being policy variables which may be varied during model tests. Calving rates, death rates and milk output per animal are endogenous model variables determined by the per-animal digestible nutrients supplied by grazing land and crop residues.

Animals in the "modern" sector are assumed to be situated on grazing reserves where adequate nutrition is available from properly managed grassland (range productivity in the modern sector is not deteriorating), and supplemental feed obtained from crop land is devoted specifically to animal production. (Land allocated to animal feed crops is a policy variable which can be substituted for land allocated to cash crops--another policy variable.) Range land available for modern grazing is determined by expenditures on grazing reserve programs. Male and female population sizes and sales, birthrates and death rates are computed, using virtually the same functional relationships but different input levels, compared to the traditional sector.

In addition to grazing reserve expenditures and supplemental feeding, the model is capable of exploring the consequences of other measures to increase efficiency and output of either the modern or traditional populations in the industry. These include programs to eradicate tsetse fly (to increase grazing areas) and herd management variables which alter sex ratios and/or control population levels to better match the available feed supply.

Several alternative performance criteria which might influence a policy maker's choice of development programs are calculated at both interim and final stages of the simulation experiment. Farm level incomes derived from meat, milk and cash crops are computed, as are capital investment and operating costs incurred through implementing various modernization policies. Thus, several relative benefit/cost relationships for experimental modernization policies are summarized by computed performance functions which include discounted net cash flows, foreign exchange balances, farm incomes, net beef imports and domestically produced nutrient outputs. The ability of the industry to meet the (forecasted) increase in demand for beef is determined by computing imports necessary to satisfy the projected demand.

Detailed Model Description

A complete description of the cattle production simulation model involves definitions of some 150 variables and parameters and specification of the structural interrelationships. A nonmathematical (and less precise) description of model structural relationships will be presented here by means of the "causal maps" of Figures 4.3 and 4.4. These maps conveniently display the interrelationships among the endogenous, exogenous and policy variables of the model. The key to interpreting Figures 4.3 and 4.4 is noting that a variable (designated by a circle) is influenced by or "a function of" all other variables which are joined, with arrows directed toward the variable in question. As indicated in the figures, endogenous, exogenous and policy variables are specifically identified according to their current status in the model.

Figure 4.3 describes the part of the model that simulates traditional and modern production over time. One general submodel or "subroutine" was constructed which simulates both traditional and modern production, depending upon whether traditional

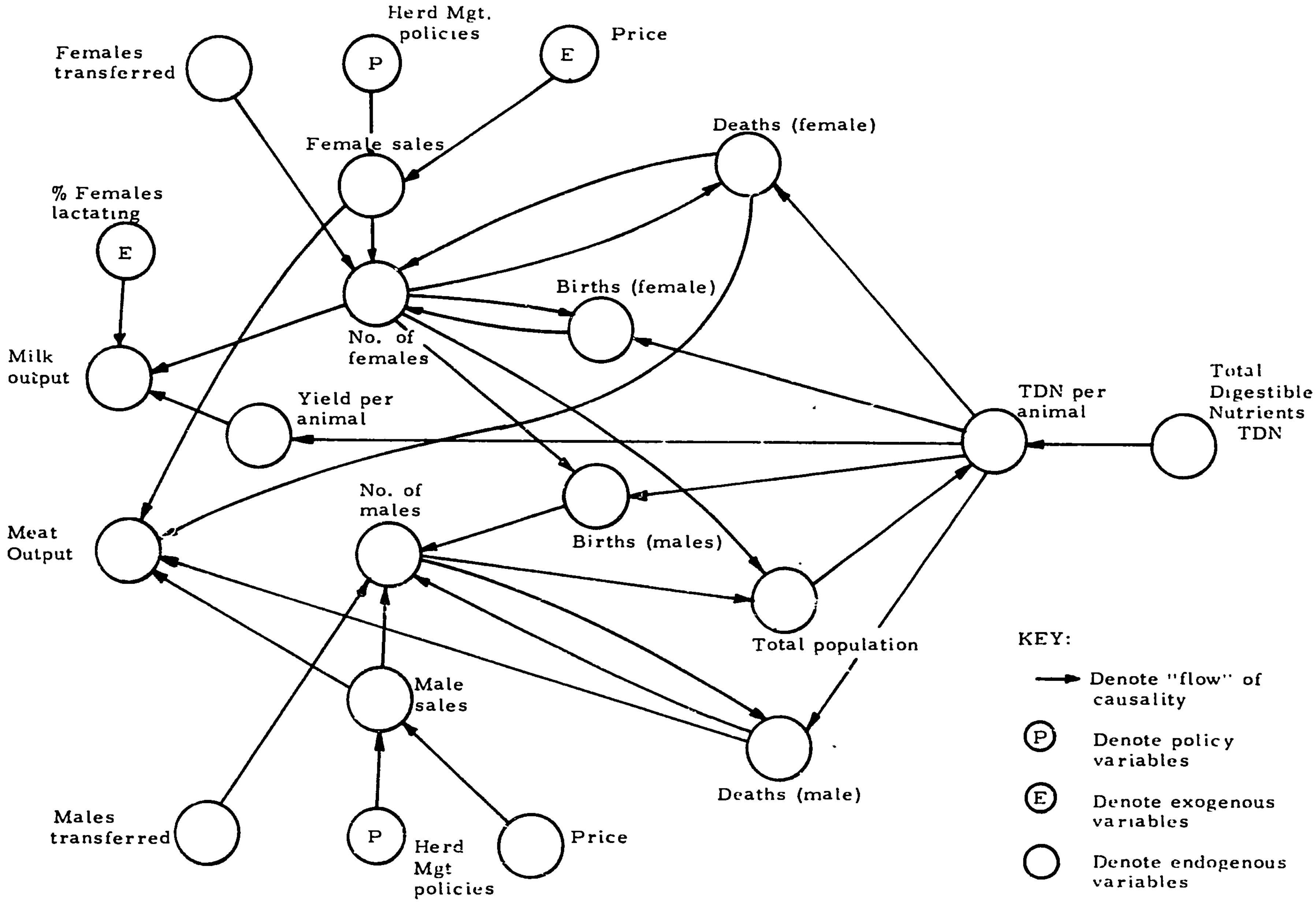

Figure 4.3 A causal map of the production sub-model.

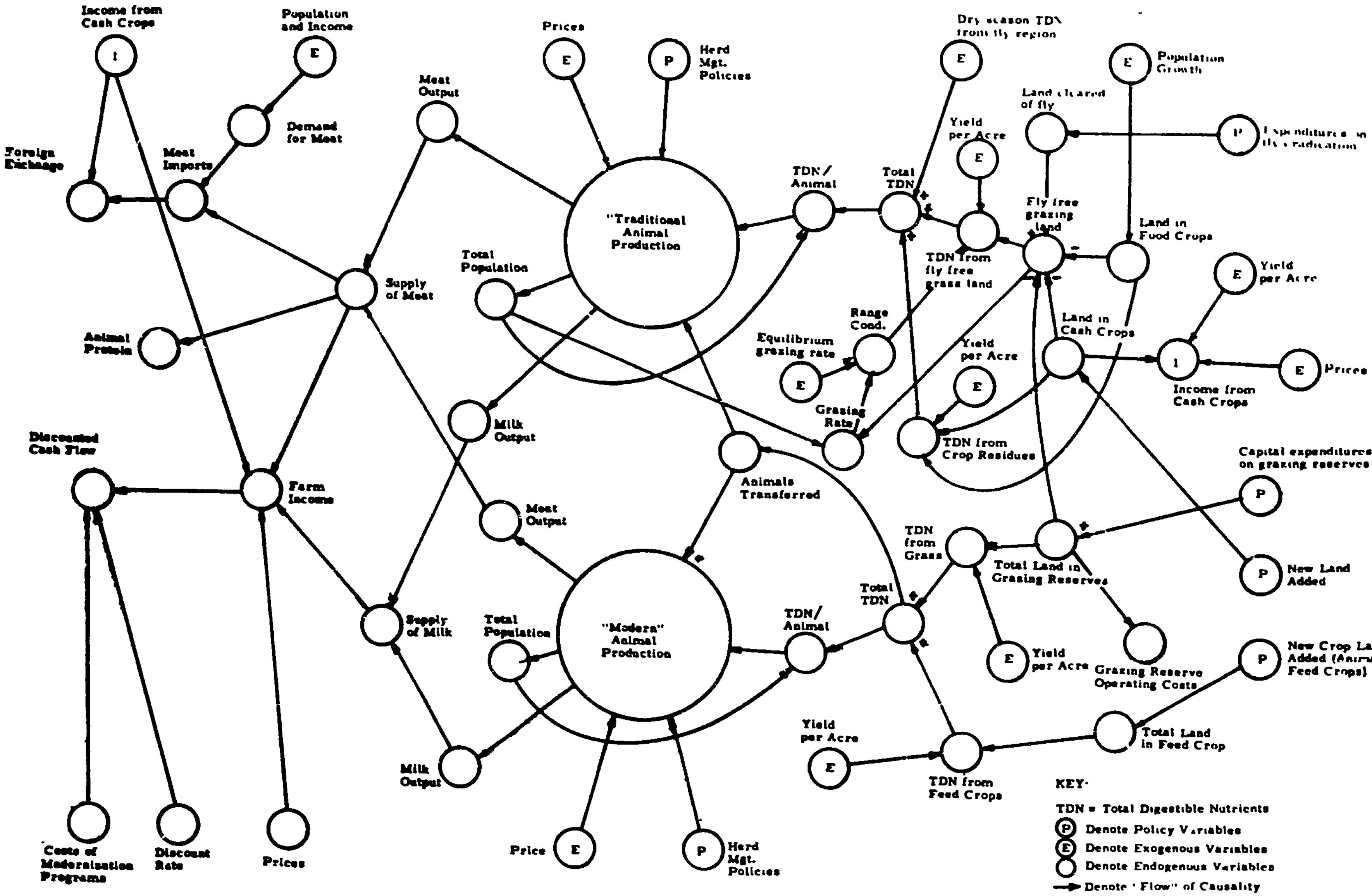

Figure 4.4 A causal map of the cattle industry simulatio~ model.

or modern data are supplied.[2/] As illustrated in Figure 4.3, animal births and deaths are a function of nutrition levels expressed in total digestible nutrients (TDN) per animal, the origin of which is detailed in Figure 4.4. The sizes of male and female populations are functions of births, deaths, sales and transfers due to modernization programs (generally, transfers are from the traditional production sector to the modern). Sales, in turn, are determined by animal prices and herd management policies, thereby permitting exploration of benefits resulting from sex ratio and/or overall population controls. Outputs of milk and meat are determined as shown in Figure 4.3. Milk output is a function of yield per animal (in turn a function of TDN per animal); the number of females in the herd and the percent of females lactating. Meat output is derived from overt sales of live animals and from the fraction of natural deaths which are normally consumed.

The causal map of Figure 4.3 is embedded in Figure 4.4 (twice to represent traditional and modern herds), which displays the cause-and-effect relationships of the cattle simulation component. This map illustrates the interrelated cause-and-effect relationships that, initiated by changes in policy variables, extend through the system and alter the measures of industry performance. The general "flow" of causality in Figure 4.4 is from right to left--from policy variables to performance variables.

An example will further describe the model structure and illustrate the significance and interpretation of Figure 4.4. We will assume that a single modernization program--development of modern grazing reserves--is initiated and use the causal map of Figure 4.4 to qualitatively trace the consequences of this policy: capital expenditures are made on development of modern grazing reserves which provide for grass conservation and adequate animal nutrition. As shown in Figure 4.4, this expenditure (after a gestation delay, which is built into the simulation model) removes grazing land from the traditional sector and, hence, alters the available nutrition in that sector. More importantly, it develops available TDN in the modern sector and initiates a transfer of animals from traditional to modern production. This transfer also affects the per-animal TDN in the traditional sector. At the same time, grazing reserve operating costs start up and increase as the program grows. After another lag, the productivity of animals transferred to the modern sector increases significantly compared to those in the traditional sector. Measures of performance such as foreign exchange, discounted cash flow and farm income change accordingly. In a similar manner, Figure 4.4 can be used to qualitatively examine the consequences of other modernization programs.

The cattle component is linked to the remainder of the Northern regional model. The most important linkages are the impact of crop land expansion upon grazing land and the TDN animals receive from crop residues. The components that simulate crop production in the Northern model are described below.

Land/Labor Allocation Component

A key factor in determining the performance of the crop sectors is the allocation of land and labor to the various production enterprises. In the model, the total arable land in the four northern subregions of Figure 2.4 is determined by available

2/ *The use of such basic model or building blocks can greatly expedite the simulation of complex systems which have a number of sectors alike in structure yet different in structural coefficients and inputs.*

labor, relevant cash returns to labor, the proportion of the farm population actively producing cash crops and a mechanization coefficient. Given total arable land, land available for cash crops is computed as a residual after subsistence food needs have been provided.[3] The land allocation mechanism then allocates this residual to the viable alternatives in each of the four subregions on the basis of cash returns per unit of labor (since labor at certain times of the year is the limiting resource in northern Nigeria). The four sets of interactions are shown pictorially in Figure 4.5. The model includes behavioral and production lags which provide for a smooth transition of cash crop land to the most profitable option available in each region. This land allocation mechanism reflects the supply response of northern producers to changes in crop prices. Since groundnut and cotton prices are established in Nigeria by marketing boards and/or world prices, only food prices are determined endogenously in the model from the interactions of supply and demand. The market component showing this interaction is described below.

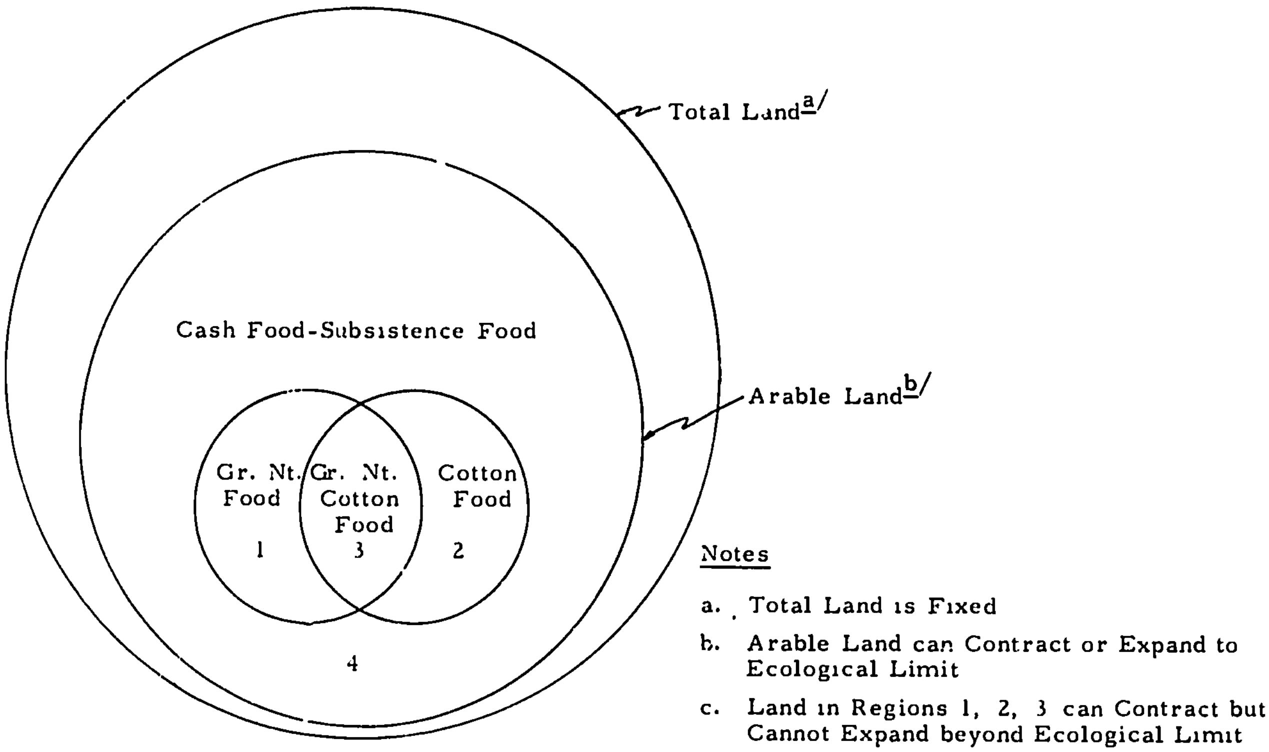

Figure 4.5. Venn diagram of the northern land allocation component.

3/ This assumption of food self-sufficiency reflects what appears to be the present situation in northern Nigeria. It is possible in the model to allow the level of self-sufficiency to be a function of other variables, i.e., prices of cash crops and food, attitude change, etc.

or modern data are supplied.[2] As illustrated in Figure 4.3, animal births and deaths are a function of nutrition levels expressed in total digestible nutrients (TDN) per animal, the origin of which is detailed in Figure 4.4. The sizes of male and female populations are functions of births, deaths, sales and transfers due to modernization programs (generally, transfers are from the traditional production sector to the modern). Sales, in turn, are determined by animal prices and herd management policies, thereby permitting exploration of benefits resulting from sex ratio and/or overall population controls. Outputs of milk and meat are determined as shown in Figure 4.3. Milk output is a function of yield per animal (in turn a function of TDN per animal); the number of females in the herd and the percent of females lactating. Meat output is derived from overt sales of live animals and from the fraction of natural deaths which are normally consumed.

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2/ *The use of such basic model or building blocks can greatly expedite the simulation of complex systems which have a number of sectors alike in structure yet different in structural coefficients and inputs.*

Agricultural Production and Marketing Component

Taking information from other components, the production and marketing component simulates the economic activities of production and marketing. The same set of equations is used for all crops of the northern region, yet each crop enters this component with its own variables. The relative simplicity and general character of the component allows it to fit all annual crops under consideration, yet be flexible enough to meet specific needs of the single crops.

The major inputs and outputs of the production and marketing component are shown in Figure 4.6. Six categories of computations are carried out:

1. Input and output relationships,
2. Wages and employment by commodity,
3. Utilization and distribution of products,
4. Farm income by commodity,
5. Taxation by commodity (if any),
6. Values added to GNP and productivity measurements by commodity.

The input-output relationships are determined by the incoming land allocated to each crop (from the land allocation component), labor required and available for each crop, the level of yield losses and mechanization. Employment is calculated by crop for the agricultural sector and for the marketing sector separately. Fixed wages per year are applied to the employment figures to provide total earned wages in agriculture (nonfamily labor) and in the marketing sector. Employment in agriculture is considered to be the minimum of the total labor demanded or of the labor available. Employment in the marketing sector is a direct proportion of total output marketed.

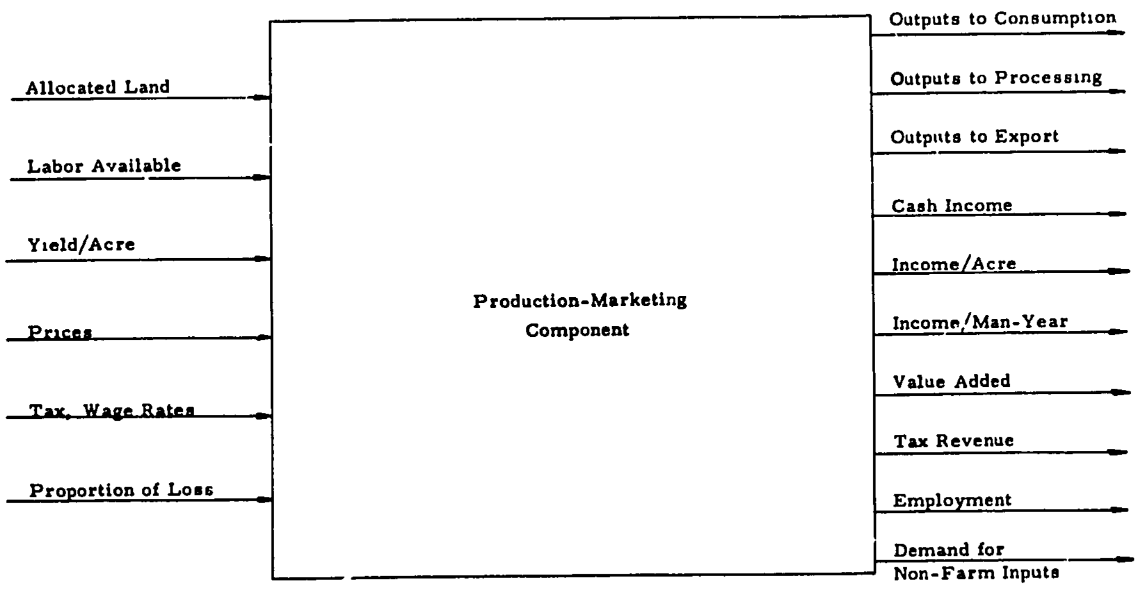

Figure 4.6. Major inputs and outputs of the production-marketing component.

The utilization and distribution of the total output of any one crop depends on the number and kinds of products derived from the primary product. A generalized set of equations that fits all crops under consideration simulates the various stages of handling, storage, and waste and/or spoilage before consumption, and the conversion and changes in product character involved in transforming primary products into secondary products.

Several income measures are calculated by this component. The largest proportion of food crops and part of groundnut production are consumed on the farm and do not enter the commercial market. Thus, subsistence income which is received in kind is one measure of income calculated. Income paid in kind is evaluated at producer prices, either the marketing board price in the case of groundnuts, or the cash price for food as determined in the market component. The producer price is derived from the market price by accounting for marketing losses, taxes paid by the traders profit margins; and a relatively strong bargaining position can shift the incidence of all losses and taxes to the farmers. Cash income is cash received for marketed crops less wages paid and cost of nonfarm inputs. The costs of nonfarm inputs are computed in the modernization component.

Total income consists of cash income and income paid in kind. However, only the cash income is considered taxable or available for nonagricultural consumer goods, education and capital investment in durable factors of production. Taxes and earnings can be given for individual crops within a region and aggregated for the entire Northern model.

Income after taxation is also approximately the returns to labor and land combined. The average returns to land and labor are calculated and used in the land allocation component for allocating land to its various uses on the basis of comparative financial returns. The production and marketing component also computes the commodity specific value added, which is utilized in the national accounts section of the nonagricultural component.

Market Component

Prices to producers for groundnuts and cotton are established by Nigerian marketing boards and are taken as exogenous to the land allocation component. Only cash food prices are taken as being established by market interactions between supply and demand.[4/] The mechanism for determining the cash food price is incorporated in the market component and serves both the Northern and Southern regional submodels (Chapter VIII). It is assumed that the weighted average price of cash food moves in response to differences between aggregate demand and supply. The weighted average price of cash food consists of prices for staple foods including guinea corn, millet, yams and cassava. It is assumed that groundnuts are not significant in the cash food market.

The aggregate supply of cash food, measured in calories per year, is the sum total of calories produced in Regions 1, 2, 3 and 4 on land allocated to cash food. The aggregate demand for cash food is computed, in part, by the population component and is a function of nonagricultural population, income and food price. The market component also allows for interregional food trade between the Northern and Southern models. Demand for food in the North is, therefore, augmented by any southern demand

4/ "Food" in the model is an aggregate of all basic foodstuffs, grains and roots, ...ch dominate Nigerian consumption.

induced by significant interregional food price differentials.[5] The food price moves in response to the degree of excess demand and the percentage change in price per unit of time per percentage excess demand existing in the market Excess demand is the difference between the quantity demanded and supplied at any given price. Thus, excess demand exists at disequilibrium prices and the prices move in such a direction so as to equilibrate demand and supply at a rate proportional to the amount of excess demand.

Modernization Component

The purpose of the modernization component is to give the production and marketing component the capability of exploring the impact of modernizing inputs upon system behavior. The primary output of this component is an average productivity (yield/acre) that reflects the extent to which modernization has taken place for a specific commodity. This average productivity is an input to the production and marketing component. However, this component can also be used to simulate the introduction of mechanization by providing changes in the mechanization coefficient, which is also utilized in the production and marketing component. This same component could also be used to simulate other types of programs where awareness, adoption and diffusion are important, such as birth control programs, nutritional and medical aid programs, etc.

In the modernization component, the rate at which modernization takes place is determined by the following factors:

1. Profitability,
2. Extension or other overt programs to introduce modern inputs,
3. Diffusion effects that propagate modern methods from farmer to farmer.

No modernization takes place unless the net return from modern practices significantly exceeds that of traditional practices. The simplifying assumption is made that seeds, fertilizer, pesticides, etc., are available and do not constrain the modernization process. The component does, however, compute <u>demands</u> for these inputs which reflect quantities necessary for modernization to proceed at the rate determined by the three factors cited above.

A detailed description of the component, including the structural equations, is given in the Appendix. The verbal description to follow centers around the causal diagram in Figure 4.7. The profitability of the modern alternative influences both the rate of adoption of modern inputs as a result of overt promotional efforts (by the extension service, perhaps) and the rate of diffusion where there is no promotional effort. The adoption rate can be influenced by government program campaigns, extension or other communication activities. Profitability can be subsidized or not, depending upon the policies established for a given simulation run. A different set of profitability equations applies for the modernization of cash crops, including groundnuts, cotton and cash food. In the case of modernization of subsistence foods, farmers are assumed to evaluate improvements in productivity through the impact they would have upon their ability to grow more cash crops.

The profitability criterion is introduced into the rate of adoption through a nonlinear function which relates the effect of profitability upon the adoption rate

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5/ *The model can also handle the (unlikely) situation in which regional price differentials create a northern demand for food from the southern region.*

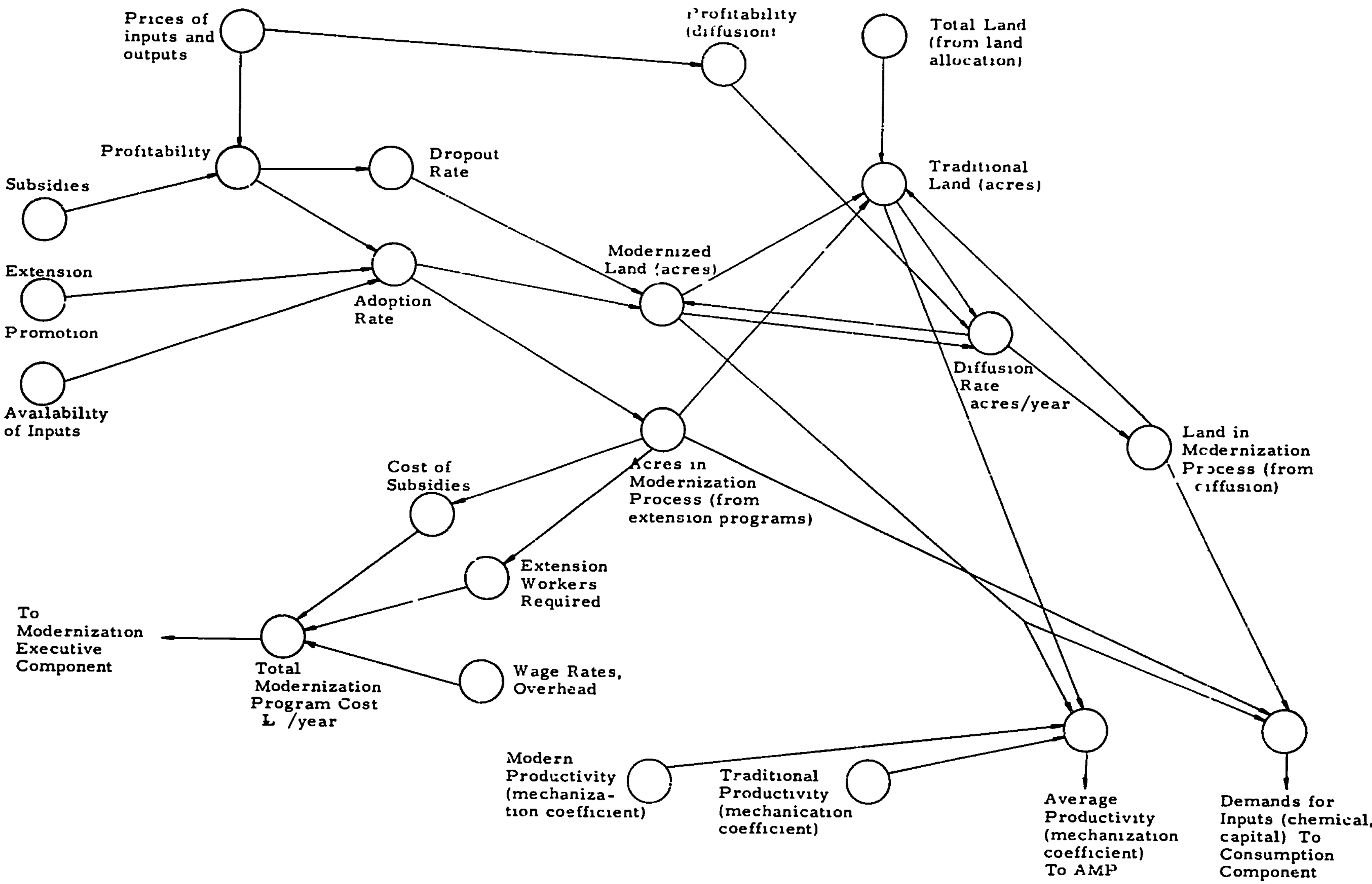


Figure 4.7. A causal diagram of the modernization component (applies to crop modernization and introduction of mechanization) — arrows indicate direction of causality.

to farmer perception of the profitability of the new methods. The function is shown in Figure 4.8. The parameter E7 indicates the maximum effect that perception of profitability could have upon the adoption rate. The parameter E9 indicates that at very low levels of perceived profitability, there may be no effect on adoption rates (threshold effect). The parameter E8 determines how rapidly the modernization rate changes with changes in the profitability criterion. Varying these three parameters would allow simulating a wide range of adoptor behavior. Farmer perception of profitability is represented by the exponentially averaged profitability, i.e., a weighted average of past profitability experiences. The profitability criterion itself is the relative (modern versus traditional) net returns to labor. Thus, the profitability is influenced by prices of both inputs and outputs.

In addition to profitability, the adoption rate is influenced by the amount of program promotion (a policy variable) expressed in units of extension worker equivalents or mass media units promoting adoption.

The quantity of modernized land (acres) is influenced by the adoption rate and the dropout rate (the rate at which farmers leave a modernization campaign and revert to traditional practices). The two rates together determine the net modernization rate from direct promotion (nondiffusion). The dropout rate is determined by the ratio of the number of extension workers (or other communication units) available to those required to sustain the modernization program. The quantity of modernized land also influences the rate of diffusion, that is, modernization that takes place spontaneously by diffusion from farmer to farmer due to the presence of examples for examination and study.

The rate of land going into the modernization process through diffusion is a direct function of the acreages of land in traditional and modern production and the perceived profitability of each. It is also an indirect function of land already in the modernization process due to overt promotion and diffusion and is constrained by the total land available not already in the modernization stream. The effect of

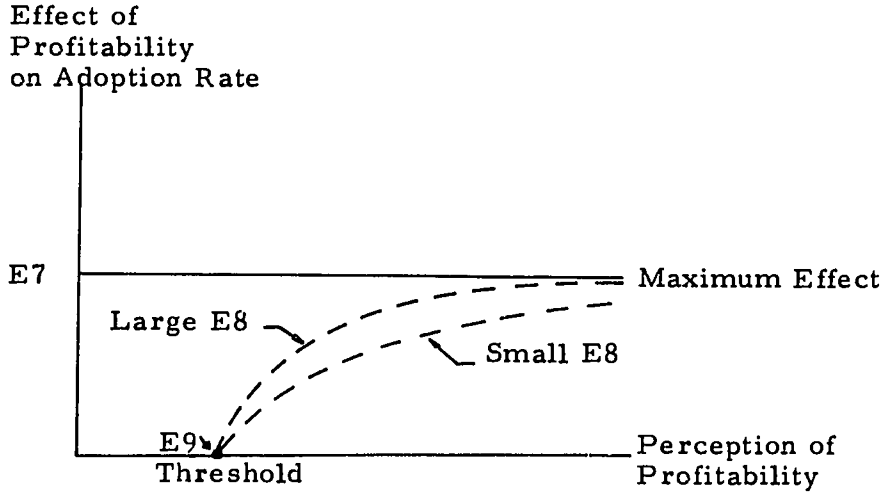


Figure 4.8. Effect of farmer perception of the profitability of new methods on the rate of annual crop modernization. E7, E8, and E9 are model parameters which govern the shape of the response function.

profitability on the diffusion rate is introduced by a nonlinear function similar to the one shown in Figure 4.8. Again, adoption of modern methods (by diffusion) will take place only if the profitability of modern practices significantly exceeds that of traditional methods. The diffusion-rate equation specifies that there is no diffusion when there is no demonstration effect. As the proportion of modernized to allocated land increases, the demonstration effect increases and, hence, the diffusion rate increases. This formulation of the diffusion rate produces an "s" shaped adoption curve similar to those found in empirical studies of the diffusion process (Carroll, 1968).

If profitability of modern methods drops significantly due to declining output prices or rising input prices, the process of modernization goes into reverse. However, the rate of recidivism to traditional methods is not symmetric to the rate of modernization. The dropout rate is a nonlinear function of (nonsubsidized) profitability as shown in Figure 4.9. If profitability is greater than some threshold value E91, there are no dropouts from modern production. For smaller values of the profitability criterion, dropout rate is some positive fraction between zero and E11. The model parameters E91, E81, and E11 can be selected to simulate a range of real-world conditions which might be appropriate for a particular development situation.

The average productivity of a given commodity is the sum of the productivities per acre times the number of acres in modern and traditional uses divided by the total land allocated to the given commodity. This average productivity is the main output of the modernization component and is used as a major input to the production and marketing component. Other outputs of this component are the demands for various modernizing inputs including biological materials, fertilizer, credit and capital investments. It also calculates the demand for technical assistance (extension-worker-equivalents and the man-units required to distribute inputs). Finally, the total cost of a modernization program can be calculated. This will subsequently be described in the modernization executive component.

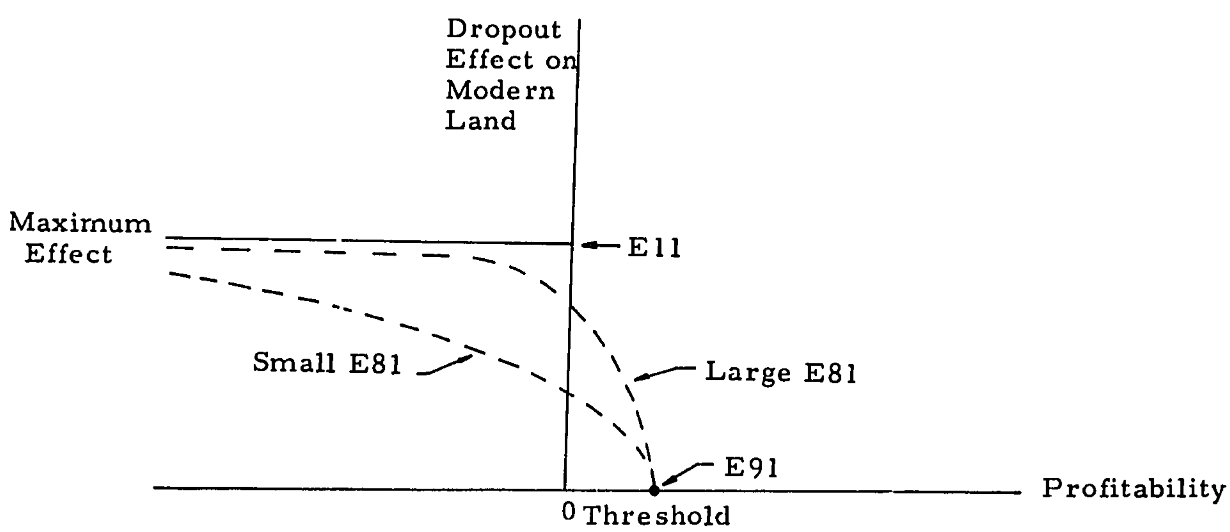


Figure 4.9. Modernization dropout effects due to falling profitability.

The Consumption and Budget

Component of the Northern Region Model

The purposes of this model component are two-fold. First, the component computes a number of agricultural sector variables needed in the nonagricultural model. These include:

1. Northern expenditures on chemical inputs (mainly fertilizer),
2. Northern agricultural expenditures on other capital inputs,
3. Northern agricultural sector expenditures on consumer goods,
4. Tax revenue from agricultural production and marketing in northern Nigeria.

Second, the component translates from commodity to regional accounts and computes income, expenditures, debt, debt service and per capita income by production region in northern Nigeria. Recall that the North in Nigeria has been conceptualized as composed of the following regions based upon soil, weather and cropping patterns:

Region 1 - Groundnuts and food (mainly grains) compete for land use.

Region 2 - Cotton and food (mainly grains) compete for land use.

Region 3 - Groundnuts, cotton, and food (mainly grains) compete for land use.

Region 4 - Food crops (mainly roots) dominate; groundnuts and cotton do not compete. (Region 4 corresponds to what is normally called the Middle Belt of Nigeria.)

In order to determine incomes and expenditures by crop region, the model computes the proportion of each commodity (groundnuts, cotton, food grains and root food) grown in each crop region. These proportions are computed on the assumption that the yields of particular commodities are the same in each region in which the commodity is produced.[6/] Given these proportions and the total commodity incomes (computed by the Agricultural Production and Marketing Component) the model computes total farm income for the four producing regions. To arrive at regional disposable income, the component computes credit requirements, interest payments, cost of farm inputs and possible multiplier effects.

The component computes regional credit requirements by converting commodity credit requirements to regional accounts through the regional proportions mentioned above. Regional debt service payments are computed on the basis of a policy variable which determines the loan repayment schedule. Given credit and debt service, the model computes the current debt by region. On the basis of these variables, regional interest payments are computed. The total farm income includes any production credit received by producers and excludes any interest payments. Regional expenditures on farm inputs are disaggregated according to chemical inputs and capital inputs to correspond to sectors of the nonagricultural model. Both these expenditure streams are summed across regions to obtain total northern expenditure on chemical inputs and capital inputs. These variables are also used in the nonagricultural model. Regional producer taxes (if any) are computed on the basis of net income after these input costs. Again, taxes are summed across regions to give total producer taxes for the Northern region model. In a like manner this component also computes taxes to the federal government from agricultural marketing.

6/ *With considerable modification to the model this assumption can be relaxed.*

From knowledge of the regional multiplier coefficient, the component computes the last item of expenditure--expenditure on goods and services produced in the rural area. The model allows for possible multiplier effects in regional income due to regionally produced and consumed goods and services such as home building, hand tool manufacture and other rural activities.

Given these income and expenditure streams, the model computes disposable income for each of the four producing regions. This computation begins by determining a variable (ADUM), which is total farm income minus total farm expenditure for each region. (Total expenditure includes cost of chemical inputs, cost of capital inputs, debt service payments, tax payments, expenditures on rural goods and services and interest payments.) If this variable is greater than some minimum level of expenditure on consumer goods (CMIN), disposable income (for nonagricultural expenditure) becomes the variable, ADUM, for each region. If ADUM is less than the minimum level (CMIN), the model assumes that credit is available to provide disposable income at the level of CMIN. In this case, disposable income becomes the variable CMIN and the regional debt is appropriately augmented. (CMIN is computed for each region as the product of the regional population and a minimum level of consumer goods consumption per capita.) Disposable income is summed across regions to give total disposable income from agricultural production for nonagricultural expenditure.

This component also computes disposable income from agricultural marketing in northern Nigeria. Disposable incomes from agricultural production and marketing are also inputs to the nonagricultural model.

Finally, the consumption and budget component computes per capita income by region. These variables provide insights into income distribution by subregions within the six northern states of Nigeria.

Operating Components

Executive Program for Northern Model

Executive program NTHEXC consists of two major parts. The first part, which can be called the initialization phase, sets initial conditions for variables and constant values for parameters of the various model subprograms. This initialization phase of NTHEXC also sets control parameters and switches (which then help direct its own activities and those of the model's subprograms).

The initialization section includes all program NTHEXC up to the beginning of the "time loop" in which TIME is incremented; i.e., the initialization phase includes all activities of NTHEXC before the actual simulation begins.

The second part of NTHEXC, which can be called the simulation phase, directs calls to the model's components, converts some output variables of one component to a form usable as input to another component, computes performance variables, compares simulation output with actual data series (if desired), and controls a small part of the model's output printing which is not directed by other subroutines, e.g., plotting of output, performance outputs and sum-of-squares measures. The second section of program NTHEXC begins with the time loop and includes the remainder of NTHEXC, i.e., this simulation phase includes all activities of NTHEXC during which the simulation calendar, so to speak, is being activated.

The Modernization Executive Component

This model component performs three major functions:

1. It permits the user of the overall model to allocate modernizing resources to a number of alternative commodities or programs. In the case of the Northern model, these alternatives currently are:
   a. introduction of modern inputs into groundnut production,
   b. introduction of modern inputs into cotton production,
   c. introduction of modern inputs into food production (in competition with groundnuts and cotton),
   d. introduction of modern inputs into food production (not in competition with groundnuts or cotton),
   e. campaigns to introduce draught animals into the:
      (1) cash-crop food and,
      (2) food-only regions of northern Nigeria.
2. The component permits the policy maker to experiment with different levels of budget expenditures for modernization programs and different distributions of budget allocations over time.
3. Once allocations are made to alternative modernization programs, this component controls the scale of the various programs so that allocated revenue is expended without excessive budget surpluses or deficits.

While developed for use in the Northern model, this component is used in the Southern model and is general enough to be used for other development models.

The general allocation procedure can be seen from the ways that total modernization revenue and its distribution over time is determined in the model. The basic input to the modernization executive component is the variable REVMN which represents the total revenue (£/year) allocated to northern modernization programs at any point in time. This variable is set by the user of the model as a policy variable. (See Figure 4.10.)

The user, by specifying the five parameters (maximum expenditure per year, initial time of expenditure, time of maximum expenditure, time of decreasing expenditure and time of expenditure end), can control the size and time distribution of modernization programs. This is the way the modernization budget is determined in the Northern model when it runs alone. When run with the Southern model, this

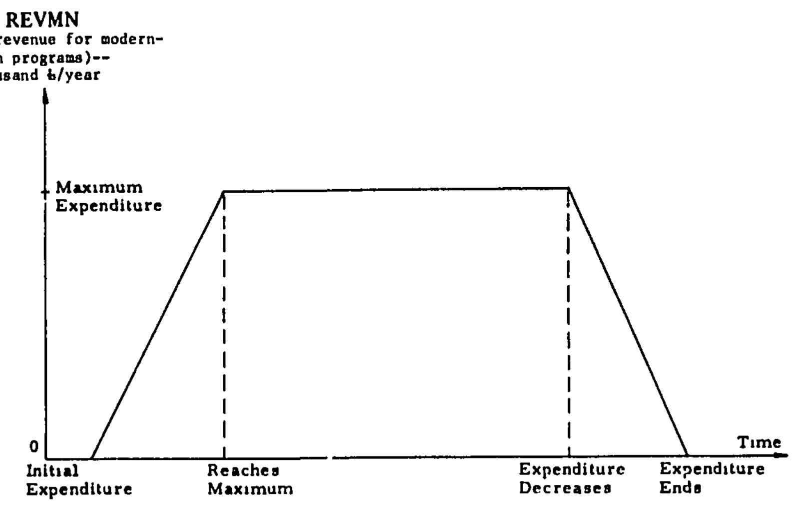


Figure 4.10. Time profile of modernization budget.

variable, REVMN, is determined at a higher policy level which allocates modernizing resources to northern and southern regions.

It should be pointed out that REVMN, in general, represents the resources allocated overtly to stimulate modernization. Therefore, it represents such public programs as extension promotion and technical assistance. It can also represent any private expenditures directed toward the same ends. The effect of this allocation is to stimulate spontaneous demands for additional modernizing inputs through diffusion processes (as shown in above modernization component).

Output-North

Five subroutines in the output component provide the results of various simulation runs. The subroutine CRTRN provides time paths (and accumulations) of various variables considered in evaluating the performance of the Northern model under various sets of behavioral, technical or policy parameters. These variables are:

1. Cash farm income from crops per year and accumulated over a simulation run,

2. Foreign exchange earnings per year and accumulated,

3. Value added from agricultural production and marketing per year and accumulated,

4. Tax revenue per year and accumulated,

5. Marketing board revenues from groundnuts and cotton per year and accumulated,

6. Cash farm income per capita in agriculture (by production region),

7. Per capita nutrition of farm people and people who buy food in the market,

8. Requirements for farm inputs including fertilizer, credit and capital goods.

A second subroutine, called RWDATN, compares input data for various variables from the "real world" with the simulated data from the model over the period 1953-65. For the Northern model, these variables are: (1) groundnut production; (2) cotton production and (3) aggregate cash food price index.

The third subroutine, SUMSQR, calculates the sum-of-squared errors between the simulated data and actual data for all the "real world" data variables, then aggregates across these variables to give a total sum-of-squares. The individual squared deviations are normalized by dividing by the mean of the real-world observations. The sum-of-squares gives one measure of goodness of fit between the simulated data and the real-world data. On the basis of this criterion, the model can be refined, and parameters adjusted to improve the degree of fit with the historical data series. This is only one measure of goodness of fit; many others could be calculated with simple modifications of the subroutine (Naylor, 1967).

A fourth subroutine, SENSIN, provides the facility for making changes in specified variables and parameters for model sensitivity tests. The fifth subroutine, called SUMRYC, prints all variables of interest in a summary fashion.

Model Data Requirements

Data requirements for the model are extensive. Aside from the descriptive information obtained from knowledgeable persons or secondary sources used to build the functional components, many coefficients and parameters must be read into the program as data input. For the Northern model, various sources of data were used, including CSNRD reports, FAO reports, Nigerian Annual Abstracts of Statistics, Agricultural Notebooks, other publisned reports, informed expert "guesstimates" and some arbitrary values which may be tested for their impact on the model through sensitivity tests. Where possible, statistical estimation procedures were used to derive coefficients from data series. More often, however, one-point estimates were obtained from published sources. Where the model is structured to allow a coefficient to change over time, estimates were usually obtained from persons with a number of years of specialized experience in Nigeria. It should be pointed out that the Northern model, as presented above, is not considered ready for use by policy makers. The model tests, to be described, disclose a number of areas where better data are required. Model implementation would entail survey research and further refinements of the model on the basis of new information.

It is not the aim of a computer model of development to forecast in absolute terms the values that will be attained by certain variables at a specified time. Rather, it is to design a development strategy by experimenting with the computer model under various assumptions and comparing the relative consequences of alternatives over time. Plans or strategies are considered acceptable only if they are relatively effective in reaching multiple goals under a wide variety of circumstances. Since it is important to consider uncertainty in the design of development strategies, one of the strengths of simulation is the feasibility of testing plans and policies under a wide variety of potential circumstances.

With a computer model, sensitivity tests are easily performed to determine whether any strategy has merit under changes in various elements of the basic data. These tests may also reveal that certain data do not have to be accurate and that the results are more sensitive to other elements in the system. Thus, an advantage of having a simulation model before too much data collection is undertaken is that later studies can be focused more sharply on the crucial data. This type of data acquisition is more a part of the application of the model than the structuring and running of the model, which is our main concern here.

The entire data input used to run the model can be found in the data statements of the computer program.[7] A partial data listing of some of the more important variables is given in the Appendix to this chapter. Tables present the numerical values of the parameters and coefficients used to run the model in its deterministic and stochastic modes. Values given under the "most likely" column correspond to the values of the parameters and coefficients used in making the deterministic runs of the model and most of the sensitivity runs. The distribution of values implied by the lower and upper limits together with the most likely values was used in the Monte Carlo runs of the model. In the latter case, the criteria variables are outputed as frequency distributions or summarized with means and standard deviations.

7/ *Space does not permit the inclusion of a printout of the complete computer program.*

Some Results From Computer Runs

This section presents some of the results from sensitivity tests, validity checks, deterministic policy experiments and Monte Carlo policy experiments performed on the cattle component and the Northern model. The first subsection gives results from the cattle component, since it was the first component built by the research team and it illustrates the types of computer simulation runs that can be made on a single component of the global model. For runs of a single component, certain variables must be assigned values which would be generated endogenously by another component if the two were run together. Thus, the results given for a single component may be somewhat different from those obtained when that component is interacting with the rest of the model. The same is true when the Northern model is run independently of the Southern model and the nonagricultural model. The second subsection below gives some results of computer simulation runs of the Northern model.

Cattle Component Results

Sensitivity tests were preceded by a careful assignment of numerical values to the many parameters of the model. These assignments were based upon the large volume of available secondary data and the educated guesses of experts with Nigerian experience. The objective was to establish a set of mean values for these parameters. These individual parameters were then varied to determine the sensitivity of the model to errors in measuring these parameters. Such knowledge improved allocation of research resources to further data acquisition. In addition, knowledge of these sensitivities is helpful to policy makers who have to choose among alternative programs.

Table 4.1 presents the results of sensitivity analyses for 11 parameters in the traditional cattle population. For those interested in reviewing how the parameter enters the equations, the 11 parameters are defined below with their computer program designation. The value assigned the parameter in the "standard run" is also given for purposes of comparison with the sensitivity runs of Table 4.1.

B3 = TDN/acre in fly-free grazing areas--156 pounds/acre

B4 = parameter determining rate of range land deterioration as a function of the difference between actual and equilibrium grazing rates--0.003

B5 = TDN/acre from food crop residues--547 pounds/acre

B6 = TDN/acre from cash crop residues--128 pounds/acre

B7 = TDN/acre in fly-infested grazing areas--241 pounds/acre

B8 = proportion of fly-infested grazing land of northern Nigeria grazed during the dry season--0.2

B12 = proportion of natural deaths marketed in the traditional sector--0.65

GRE = equilibrium grazing rate--8 acres/animal-year in fly-free area--that grazing rate which will maintain the existing range condition[8/]

[8/] *Since animals spend only part of the normal year in the fly-free area, this rate is adjusted downward accordingly from yearly figures.*

TABLE 4.1
Sensitivity Analyses on Selected Parameters of the Cattle Component.

Run	Parameter Changed and Base Value ( )	Female Population PFT (million)	Male Population PMT (million)	Range Condition RCON (index)	Farm Income from Milk and Meat FARM I (million)	Accumulated Discounted Income CF (billion)	Foreign Exchange Earnings FOREX (billion)	Remarks
1		5.715	2.067	.671	84.4	1.15	21 7	Standard run[a]
2	BF3 (156)	5.843	2.111	.662	85.7	1.17	22.5	TDN from grazing at 172 lbs./acre
3	BF4 (.003)	5.673	2.051	.639	84.0	1.15	21.5	Higher rate of range land deterioration (BF4 at .0033)
4	BF5 (547)	5.979	2.166	.660	87.0	1.17	23.2	TDN from food crop residue at 602 lbs./acre
5	BF6 (128)	5.722	2.070	.670	84.5	1.15	21.8	TDN from cash crop residue at 141 lbs./acre
6	BF7 (24[illegible]	5.842	2.113	.664	85.7	1.16	22.4	TDN from fly-infested grazing at 265 lbs./acre
7	BF8 (.2)	5.842	2.113	.664	85.7	1.16	22.4	Proportion of fly-infested land grazed at .22
8	BF12 (.65)	5.715	2.067	.671	85.4	1.17	23.1	Proportion of natural deaths marketed at .715
9	CRE (8)	5.620	2.030	.602	83.5	1.15	21.2	Equilibrium grazing rate at 8.8 acres/animal
10	LG_o	5.931	2.145	.702	86.6	1.17	22.9	Area of fly-free grazing at 40,700,000 acres
11	PMT_o	5.713	2.067	.671	84.4	1.15	21.[illegible]	Initial size of male herd at 3,476,000 animals
12	PFT_o	5.709	2.064	.664	84.4	1.18	21.7	Initial size of female herd at 6,424,000 animals
13	b/	[illegible].262	1.15[illegible]	.216	60.4	.983	8.4	Worse nutrition case[b]
14	c/	8.988	3.274	.866	116.5	1.37	39.6	Best nutrition case[c]

a/ Tabulated values computed at the end of 30 year simulations. All monetary values are in Nigerian pounds.
b/ TDN from food crop residue, cash crop residue, fly-infested grazing at 360, 100 and 200 lbs./acre, respectively, proportion of fly-infested land grazed at .1 and equilibrium grazing rate at 15 acres per animal.
c/ TDN from food crop residue, cash crop residue, fly-infested grazing at 950, 150 and 362 lbs./acre, respectively, proportion of fly-infested land grazed at .33 and equilibrium grazing rate at 5 acres per animal.

LG_o = initial (at start of model run) area of fly-free grazing land--37,000 acres

PFT_o = initial size of traditional female herd--5,840 thousand animals

PFM_o = initial size of traditional male herd--2,160 thousand animals

Results from Run 1, the so-called "standard run" are shown in the first row of Table 4.1. Values of certain endogenous variables after 30 years of simulated time are tabulated for comparison with the results from sensitivity runs. With the mean values of parameters, the traditional herd size remained virtually constant over the 30-year period (8 million initially and 7.8 million at the end of 30 years) and the range condition deteriorated to 67 percent of its initial value.

In Runs 2 through 12 of Table 4.1, individual parameters are successively increased by 10 percent and the influence on the endogenous variables are tabulated. The left-hand side of the table shows the parameter which was varied along with the assumed value. The results in Table 4.1 indicate that TDN per acre of fly-free grazing, TDN per acre from food crop residues, initial area of fly-free grazing land and the proportion of natural deaths marketed more significantly affect model behavior than do the other parameters of the sensitivity analyses. Interestingly, changes in the initial cattle population do not strongly affect the behavior of model performance variables. This is encouraging in light of the uncertainty existing vis-a-vis these numbers.

Runs 13 and 14 were made using worst and best case estimates of available nutrition. As indicated, wide variations in herd sizes and income levels resulted. Worst/best case populations at 30 years ranged from 4.4 million to 12.3 million animals. These results underline the importance of adequate nutrition to the productivity of the northern Nigerian cattle industry.

Initially, a limited number of computer runs were made to explore alternative modernization programs for the cattle industry of northern Nigeria. These results are summarized in (Johnson, 1968), where the influence of a number of alternative modernization programs upon a series of performance variables is tabulated. While conclusions regarding policies for northern Nigeria should not, and cannot, be drawn from these preliminary results, they illustrate how the model might be used.

In addition to the above sensitivity runs and policy experiments, Monte Carlo runs were also made using the cattle production component. In the Monte Carlo runs, certain parameters are assigned a frequency distribution instead of merely a mean value.

These distributions can reflect variability inherent in the parameter itself or uncertainty in the state of knowledge about the parameter value. Then various runs are made of the model in which different policies are assumed implemented and frequency distributions of outcomes or performance variables are obtained as output. In effect, for each run of the model with a specified policy, the model draws parameter values from the specified distributions at random. After a number of runs, perhaps 100 to 200, the results are tabulated and the output variables are summarized in a mean and standard deviation. Results from Monte Carlo runs can be helpful to policy makers if the distribution of outcomes of policy implementation is so diffuse that worse outcomes outweigh any possible best outcome, and looking at only the mean values may be misleading and cause the policy maker to implement an undesirable (highly variable) policy alternative. Since we do not have a welfare function for summarizing these outcome distributions, the best that can be offered is the range, variance and other characteristics of the distribution for the policy maker's inspection and consideration. These results also permit the construction of confidence limits on outputs under various policies.

The results from some Monte Carlo runs are given in Table 4.2 for four policy alternatives.[9/] The parameter values of the distributions used in the Monte Carlo runs are given in the appendix to this chapter. The performance variables are shown across the top of Table 4.2 and the policy alternatives are listed on the left side. For each policy, alternative results are shown, using the most likely value of the parameters in the appendix and the distributions given there as well. The mean and the standard deviation are given for those Monte Carlo runs for which the distributions were used. Thus, the run designated by an "a" along the right side of the table used the most likely value of the parameter. Runs designated with a "b" used the distributions. The standard deviations of the performance variables using the distributions are given in parentheses.

9/ *These policy runs are based upon better data than those of (Johnson, 1968).*

TABLE 4.2
Some Monte Carlo Simulation Runs made with the Beef Production Component.

Run	Female Population PFT (million)	Male Population PMT (million)	Range Condition RCON (index)	Total Northern Farm Income YA + YM + YCC FARMI (million)	Discounted Net Returns CF (billion)	Foreign Exchange Earnings FOREX (million)	Income from Animals (Meat) YA (million)	Income from Milk YM (million)	TDN per Animal TDNAT (thousand)	Initial Female Population PFT(0) (million)	Initial Male Population PMT(0) (million)	Expenditure on Fly Eradication £ Millions/yr. C18 (million)	Population Control Parameter CSFT	Policy Alternative
1a	3.712	1.748	.7801	117.2	1.174	96.63	13.16	27.91	1.919	5.10	2.40	0.	0.	Standard Run[b]
1b	3.835	1.832	.7814	119.4	1.196	98.42	14.59	28.66						(no improvement
SD[a]	(.781)	(.379)	(.1557)	(7.44)	(.0533)	(4.980)	(2.970)	(4.820)						programs)
2a	4.000	1.891	.8121	119.6	1.170	97.56	13.85	29.69	1.981	5.10	2.40	1.000	0.	Annual Fly Eradi-
2b	4.155	1.991	.8176	122.2	1.192	99.51	15.40	30.65						cation Expenditure
SD	(.823)	(.401)	(1330)	(7.84)	(.0540)	(5.110)	(3.130)	(5.080)						of 1 £ Million
3a	2.808	1.476	.9664	112.0	1.115	98.02	13.55	22.31	2.496	5 10	2.40	0.	1.000	Population Control
3b	3.029	1.591	.8494	114.5	1.141	99.37	14.72	23.68						to Increase per
SD	(.497)	(.279)	(.1172)	(5.36)	(.0491)	(5.350)	(3.080)	(3.070)						Animal Nutrition
4a	3.139	1.634	9017	114.8	1.111	98.99	14.30	24.36	2.518	5.10	2.40	1.000	1.000	Fly Eradication
4b	3.412	1.771	.8875	117.8	1.139	100.5	15.61	26.04						Program and Popula-
SD	(.527)	(.295)	(.0977)	(5.67)	(.0501)	(5.570)	(3.290)	(3.250)						tion Control
5a	2.814	1.480	.8748	112.0	1.083	98.06	13.58	22.35	2 496	3.825	1 800	0	1.000	Same as Run 4 with
5b	3.035	1.594	.8569	114.6	1.108	99.41	14.75	23.71						Reduced Initial
SD	(.497)	(.279)	(.1133)	(5.36)	(.0476)	(.536)	(3.090)	(3.070)						Populations

a/ SD denotes standard deviations based upon 200 simulation runs. b/ Tabulated values computed at the end of 20-year simulations. All monetary values are in Nigerian pounds.

A careful examination of the results in Table 4.2 indicates some interesting trade-offs for the various policy alternatives. For example, consider the alternative of fly eradication coupled with population control. This alternative provides the highest level of nutrition per animal (TDN per animal) and the highest income from beef. It shows a smaller number of animals on the range, both male and female, than the base run, resulting in an improved range condition, but a lower income from milk and a lower discounted net return. It also results in higher foreign exchange earnings than the base run, since beef and cash crops (nonfood) are exported. Another interesting point to note in the table is the large proportion of income derived from milk. Clearly, it is unsound to deal with this industry in a policy sense as a "beef" industry.

The policy alternatives explored in Table 4.2 deal with improvements in the traditional (Fulani) animal population. These results are certainly not encouraging if dramatic improvements in the Nigerian cattle industry are sought. It seems evident that programs directed at radically different production systems must be devised to improve productivity significantly.

Preliminary Tests of the Northern Model

The major components of the Northern model were programmed, simulated and tested individually as part of the overall model-building process. During this process, conceptual and programming errors were detected and corrected, and the components were then integrated into the Northern model. Extensive model tests were performed on the larger model to eliminate programming errors and inconsistencies between related model components. This refinement process led to a model, the output of which was considered ready for comparison with time series data generated by the northern Nigerian economy. The information produced by these validity checks provided guidance for determining priorities for data-gathering activities. These tests also suggest those parameters about which current knowledge is uncertain and future data-gathering would improve the model's behavior in comparison to "reality."

The procedure for making the validity tests is shown in Figure 4.11. Prices to farmers for groundnuts and cotton over the period 1953-65 were used as input to the Northern model. Since these prices were determined largely by world prices and/or marketing board policies, they can be considered exogenously determined. The model then simulates this 13-year period, generating annual groundnut and cotton production and an aggregate cash food price index for northern Nigeria. The sum-of-squared errors between simulated data and actual data was then calculated and aggregated.[10] These total sums-of-squares summarize the model errors and provide a basis for refining the model. Model parameters about which knowledge was uncertain were adjusted within the likely range of actual values until they coarsely tracked real-world data and produced a respectable value for the total sums-of-squares. A plot of a typical series for simulated groundnut sales is shown in Figure 4.12 together with the actual sales. Producer prices, the input to the model, is also shown.

Following this coarse tuning of the model, a "standard run" of the model was established, and a series of "sensitivity runs" of the model were made in which individual model parameters were varied by 20 percent. Results from these sensitivity tests show the impact on total sums-of-squares and other performance criteria such as regional income, foreign exchange and per capita income. Some of the more important results of these runs, shown in Table 4.3, are merely indicative of the kind of output volume that can be generated with the Northern model.

10/ *The following equations define the total sums-of-squares:*

$$TSS = TSS_G + TSS_C + TSS_F$$

where:

TSS = total sum-of-squared deviations of the model from actual data

TSS_G, TSS_C, TSS_F = total sum-of-squared deviations of groundnut, cotton and food series, respectively.

The individual squared deviations, TSS_G, TSS_C, and TSS_F are computed as follows:

$$TSS_i = \sum_{j=1}^{13} \left[\frac{X_{ij} - \hat{X}_{ij}}{\bar{X}_i} \right]^2$$

where:

X_{ij} = real-world observation in year j

$\bar{X}_i = \sum_{j=1}^{13} \frac{X_{ij}}{13}$ --mean of real-world observations

X_{ij} = the simulated value of the i^{th} time series in year j.

Division by the mean $\bar{X}_i$ in this equation normalized the errors of each time series so they carry approximately equal weight in the overall measure of fit, TSS. As is seen from these equations, perfect tracking would correspond to a TSS value of zero.

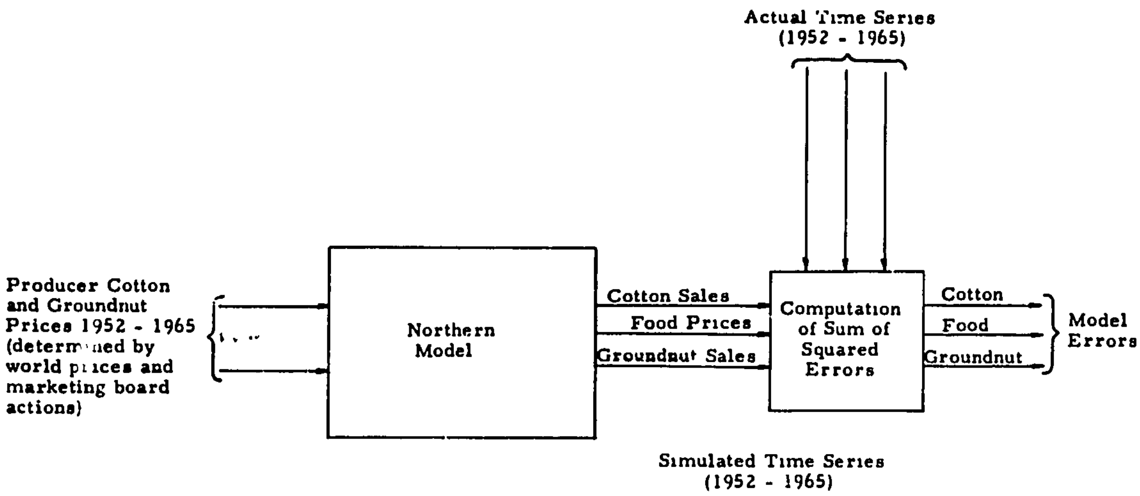


Figure 4.11. Diagrammatic descriptions of tests of the northern model against actual data generated by the economy ' ` 52-1965).

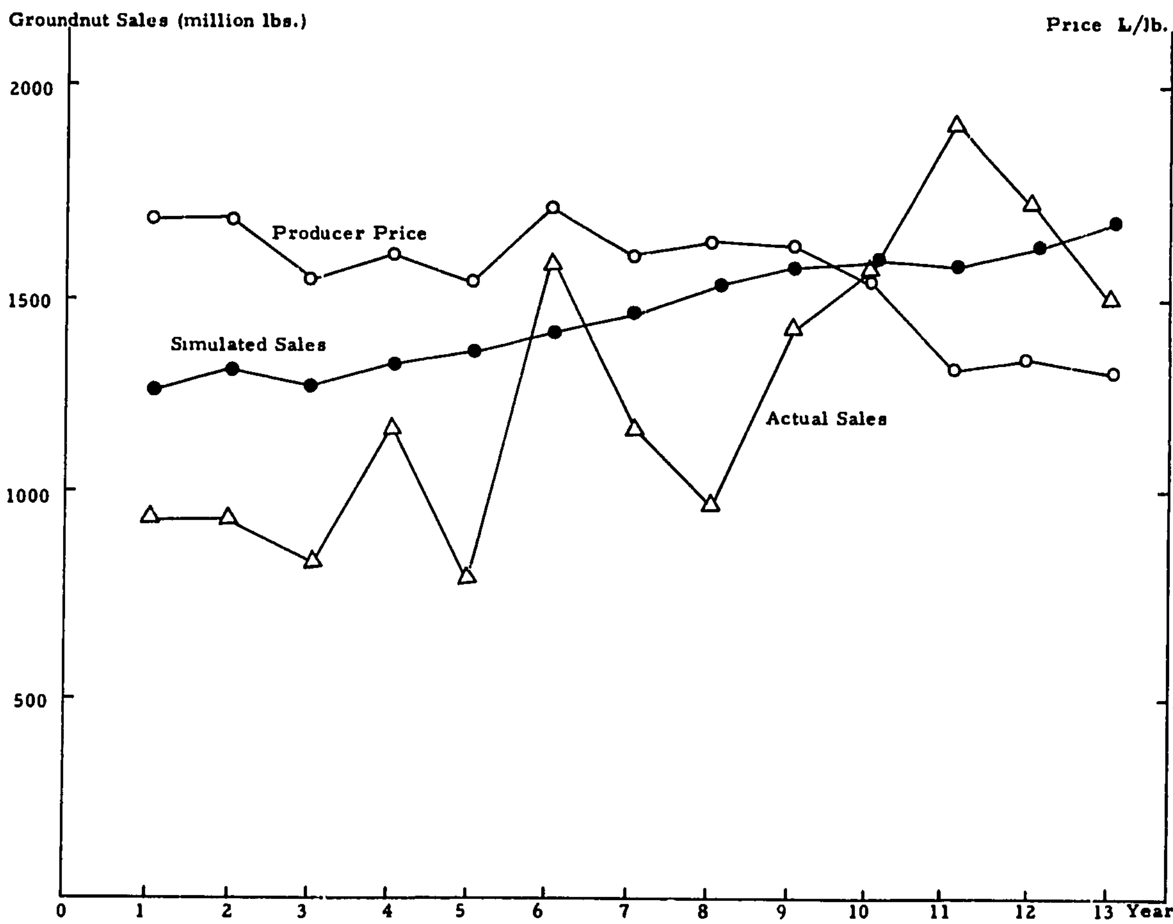


Figure 4.12. Results of "coarse" model tuning–groundnut time series against simulated series (with groundnut producer prices).

TABLE 4.3
Selected Results of Northern Model Sensitivity Tests.

Run	Cash Farm Income from Crops CFICNA (billion)	Foreign Exchange Earnings from Crops and Cattle FOREXNA (million)	Cash Farm Income Per Capita Rural CFIPC (pounds)	Total Sum-of-Squares TSS	Sum-of-Squares Food Prices TSS_F	Sum-of-Squares Groundnut Production TSS_G	Sum-of-Squares Cotton Production TSS_C	Remarks
1	1.890	9 228	8.29	1.887	.200	.828	.859	Standard Run[a]
2	2.026	172.7	8.57	4.896	.200	3.837	.859	Cultivated acres per man increased 20 percent in region 1
3	1.945	87.00	8.44	7.463	.200	.827	6.436	Cultivated acres per man increased 20 percent in region 2
4	1.922	45.42	8.32	2.369	.200	1.309	.859	Percent of rural population economically active increased 20 percent in region 1
5	1.895	15.29	8.29	2.122	.200	.828	1.095	Percent of rural population economically active increased 20 percent in region 2
6	1.890	9 228	8.29	1.887	.200	.828	.859	Response to profitability increased by 20 percent in region 1
7	1.891	9.309	8.29	1.872	.185	.828	.860	Response to profitability increased by 20 percent in region 4
8	1.886	3.189	8.26	1.893	.200	.834	.859	Response to profitability increased by 20 percent for region 1 when profitability is low
9	1.894	14.26	8.30	1.904	.200	.844	.859	Rate of change of economically active population increased 20 percent in region 1
10	1.895	15.14	8.29	2.085	.200	.828	1.057	Rate of change of economically active population increased 20 percent in region 2
11	1.891	9.293	8.28	1.874	.1864	.828	.859	Rate of change of economically active population increased 20 percent in region 4
12	1.891	9.[illegible]79	8.28	1.892	.206	.828	.858	Rate of food price change increased 20 percent
13	1.888	11.010	8.26	2.045	.328	.828	.889	Ratio of effective to actual labor force increased by 20 percent (mechanization)
14	1 989	130.3	8.51	3.699	.200	2.639	.859	Yield per acre increased 20 percent for groundnuts
15	1.921	52.7[illegible]	8.37	4.438	.200	.828	3.410	Yield per acre increased 20 percent for cotton
16	2 007	156.7	8.54	5.452	.200	2.428	2.825	Yield per acre increased 20 percent for food in regions 1, 2 and 3
17	1.890	8.396	8.25	1.949	.248	.828	.874	Yield per acre increased 20 percent for food in region 4

a/ Tabulated values computed at the end of 20 years simulations.

The first run in Table 4.3 provides a standard for evaluating subsequent runs. In Runs 2 through 17, a parameter listed below and indicated under the "remarks" column of Table 4.3 (and only that parameter) is changed by 20 percent, and the impact upon measures of system behavior noted. In addition to a tabulation of values of total sums-of-squares (TSS), sums-of-squares for food prices (TSS_F), sums-of-squares for cotton production (TSS_C) and sums-of-squares for groundnut production (TSS_G), which are measures of how well the model fits data from the northern Nigerian economy, Table 4.3 includes a number of economic measures which provide an indication of the importance of variations in any given parameter in determining the performance of the economy. These are: (1) cash farm income from crops in northern Nigeria accumulated over a 20-year simulation period; (2) foreign exchange earnings from crops and cattle in northern Nigeria accumulated over a 20-year simulation period, and (3) cash farm income per person in the rural economy of northern Nigeria. Sixteen parameters were tested for sensitivity providing the results of Table 4.3. These are defined as follows with the value of the parameter for the standard run.

$APLO_1$ = cultivated acres per equivalent man-unit in Region 1 (groundnut-food) with traditional mechanization and normal prices--6.0 acres (varied in Run 2)

$APLO_2$ = same as above for Region 2 (cotton-food)--6.0 acres (varied in Run 3)

EAP_1 = proportion of rural population that is economically active in Region 1 (groundnut-food) at the beginning of the simulation run (1953)--0.750 (varied in Run 4)

EAP_2 = proportion of rural population that is economically active in Region 2 (cotton-food) at the beginning of the simulation run (1953)--0.5 (varied in Run 5)

$B_{1,1}$ = profitability elasticity for groundnuts when profitability index (PF_1) is greater than one--1.0 (varied in Run 6)

$B_{1,4}$ = profitability elasticity for food in Region 4 when profitability index (PF_4) is greater than one--1.0 (varied in Run 7)

$B_{2,1}$ = profitability elasticity (Equation (11)) for groundnuts when profitability index (PF_1) is less than one--0.5 (varied in Run 8)

$CL7_1$ = a parameter that determines the rate of change of the economically active population in Region 1 (groundnut-food)--0.05 (varied in Run 9)

$CL7_2$ = a parameter that determines the rate of change of the economically active population in Region 2 (cotton-food)--0.1 (varied in Run 10)

$CL7_4$ = a parameter that determines the rate of change of the economically active population in Region 4 (food only)--0.03 (varied in Run 11)

CL5 = a parameter that controls the rate of food price adjustment in response to differences between supply and demand--1.0 (varied in Run 12)

CM_4 = mechanization coefficient in Region 4--the ratio of "effective" to actual labor force--1.0 (varied in Run 13)

PYT_1, PYT_2, PYT_3, PYT_4 = the productivities in yield per acre in commodities of the Northern model, groundnuts--700 pounds/acre, cotton--260 pounds/acre, food grain--700 pounds/acre, root food crops (in Region 4)--5,320 pounds/acre (varied in Runs 14-17).

From Runs 2 through 5, variables such as acres cultivated per unit of labor and indices of economic activity are seen to be quite important in determining the performance of the model. This suggests that effort directed at obtaining better estimates of these parameters might substantially improve model accuracy. In fact, comparison of Runs 2 through 5 with Runs 6 through 8 suggests that these parameters might be more important in determining system behavior than parameters which measure the impact of prices upon subsequent enterprise selection decisions.

Runs 9 through 11 test the impact of the parameters which determine the rates of change in the "economically-active" population in the northern subregions. These parameters are seen to have some impact upon model performance but less than might have been expected.

In Run 12, the food price adjustment parameter was examined for sensitivity and found to have a relatively weak influence upon model behavior. This suggests that high precision may not be necessary here and that data-gathering efforts might be more profitably directed elsewhere.

In Run 13, it was assumed that farmers in the subregion who specialized in food adopted mechanization which effectively increased labor productivity 20 percent. This resulted in lower food prices (and improved nutrition) for the consumer but tended to reduce farm income slightly under current behavioral assumptions.

Perhaps the most interesting simulation results contained in the table are those of Runs 14 through 17. In these runs, it was assumed that yields per acre were increased by 20 percent for each of the four major crop activities of northern Nigeria. Run 14, with increased groundnut yield, showed significant increases in foreign exchange earnings and farm income. In Run 15, the impact of a corresponding increase in cotton yield was less significant due to the smaller scale of cotton production.

Run 16 postulated a 20 percent increase in the yield of food (mainly grains) grown <u>in competition with groundnuts and cotton</u>. The impact on foreign exchange earnings and farm income was greater than when either groundnut or cotton yields were increased by the same proportion, since increased food yields allowed farmers to release land and labor from food crops. Hence, the acreage and outputs of groundnuts and cotton increased more than the previously cited case due to the very large acreage of food crops in the subregions. These results focus attention on an important question: Should extension and research programs give more emphasis to food crops grown in competition with crops such as groundnuts and cotton? Much current thinking seems to be aiming these resources directly at the export and import substitute commodities. These questions will be examined again in the section below on policy experiments.

In Run 17, the yield of food in the food-only zone was increased by 20 percent as in Run 13, food prices were lowered and the impact on farm income and exchange earnings was neutral.

Monte Carlo Runs of the Northern Model Under Alternative Strategies for Agricultural Development

Following the sensitivity runs described above, a limited (approximately one man-month) effort was expended to improve the quality of the data included in the Northern model. Wherever possible and desirable, estimates were obtained from knowledgeable researchers with Nigerian experience for lower limit, upper limit and most likely values for key model parameters. With this information it was possible to run the Northern model in a "Monte Carlo" mode as described above in connection with the cattle component; that is, for a given program or policy, the model is run a number of times with key parameters drawn from probability distributions. Means and standard deviations of outcomes (per capita income by region, foreign exchange earnings, per capita nutrition, etc.) are then computed. The appendix to this chapter contains the lower limit, upper limit and most likely values included in Monte Carlo runs of the Northern model.

These Monte Carlo runs centered around what appear to be the more important policy options facing planners vis-a-vis the development of the agricultural sector of northern Nigeria. Of interest are modernization programs to introduce improved production practices into the major commodities of the region--groundnuts, cotton, food grains and root foods. Also of interest are marketing board price policies that would stimulate export crop production through increased producer incentives. Table 4.4 summarizes the results of a number of simulation experiments designed to explore policies based on these factors.

The first experiment of the table is a standard against which other experiments can be compared. This run assumes that no programs are instituted to modernize commodities of the area and that marketing board price policies for groundnuts and cotton are adverse to farmers in that they generate surplus revenue by lowering prices paid to producers. The assumption is made in this run that marketing boards for groundnuts and cotton withhold 25 percent of the market value of the product in addition to normal costs of providing marketing services. In this (and the other experiments of Table 4.4), the model was calibrated to approximately track the performance of the northern Nigerian agricultural economy over the period 1953-65 and then projected to the year 1985. The values of the criteria of Table 4.4 are for the year 1985. The upper numbers tabulated for each experiment are the mean values for criteria computed from 100 repetitions of the experiment carried out with different sets of random parameter values. The numbers in parentheses are the standard deviations of the 100 experimental outcomes of each criterion variable.

Experiment 2 is a deterministic version of Experiment 1; that is, it contains the same policy assumptions as No. 1 but was run with most likely values assigned to all parameters (see tables at the end of the appendix to this chapter).

Some points should be noted before discussing the results of other simulation experiments. Foreign exchange earnings in these and some subsequent experiments are negative due to the high projected imports of cattle required to meet domestic demand. The model indicates that, with the existing cattle production system, the gap between domestic supply and demand of beef will widen substantially through 1985. A second point to be noted is the wide gap between cash per capita income in Region 4 (root food crops) and Regions 1, 2 and 3 (food grains, groundnuts and cotton). The model indicates that most of the food sold in the cash market is produced in Region 4, since food grains cannot normally compete with groundnuts and cotton as a source of cash income in Regions 1, 2 and 3 (even at the relatively high food prices that prevail in 1985). The relatively high yields of root foods (yams and cassava) result in relatively high earnings per acre and per unit of labor wherever these crops are produced and marketed. This would produce some of the above noted disparity. It is also possible that error in (underestimating) the farm population in Region 4 is an additional source of disparity. Further research is needed in this particular segment of the Northern model.

An additional point should be noted before comparing the alternative development programs of Table 4.4. Note that the deterministic version of Run 1 (Run 2) varies considerably in its criterion variable values from the means of Run 1. This is due to the fact that many of the probability distributions for parameters in the model are skewed. That is, the most likely values (modes) of the distributions may be considerably different from the means of the distributions. An important source of difference between Experiments 1 and 2 is the skewedness of the probability distributions that determine rates of rural-urban migration in the model. For example, the most likely value for the migration of rural males was taken as 0.75 percent/year (the value used in Experiment 2). The lower and upper limit values used in Monte Carlo runs were, respectively, 0.5 percent/year and 4.0 percent/year (see tables in the appendix to this chapter). This high rate of rural-urban migration accounts for much of the increase in food price and Region 4 per-capita income noted in Experiment 1 over Experiment 2.

Experiment 3 included extension campaigns to introduce improved practices into the production of groundnuts and cotton without associated marketing board price policies to stimulate producers. Five million £/year were allocated over the period 1965-74 to promotion, technical assistance and subsidies for improved production of groundnuts and cotton. The expenditure was allocated two-thirds to groundnuts and one-third to cotton. As noted in the table, substantial improvements in the mean values of income, value added, foreign exchange earnings, etc., occurred as a result of this policy. In effect, the extension campaigns triggered farmer-to-farmer diffusion of improved production practices, and significant increases in overall productivity of these commodities have resulted. This was possible because the net return to labor with modern practices was significantly higher than with traditional practices. It is important to note that this differential profitability does not exist unless the "modernization package" includes a labor-saving component to ease the demand for labor during crucial times in the production cycle.

Experiment 4 assumes no modernization campaigns, but includes groundnut and cotton marketing board policies which do not extract revenue above operating expenses, resulting in significantly higher producer prices. Again, measures of performance are improved, particularly per-capita incomes which are directly stimulated by increased producer prices. Measures such as export earnings and value added are less significantly improved than under the conditions of Experiment 3.

In Experiment 5 the modernization budget of Experiment 3 (£5 million/year over the period 1965-74) is allocated to the modernization of food grains that compete with groundnuts and cotton in Regions 1, 2 and 3. Mean per capita incomes are improved over the standard (Experiment 1), though less so than with the same resources allocated to modernization of groundnuts and cotton (Experiment 3). This increase is due primarily to the increase in food output releasing land and labor for the production of more cash earners (groundnuts and cotton). The relatively smaller increase than that of Experiment 3 is due to slower diffusion rates in the much larger land areas allocated to the food grains. (The model assumptions which lead to this behavior should be carefully examined for validity.) Note also from Table 4.4 that measures of value added are reduced somewhat over the standard (Experiment 1). This is due to the lowering, somewhat, of food prices caused by the increase in productivity of food land. This lowering of food prices occurs in late years of a simulation run when cash crops are less profitable due to forecasted declines in world prices of groundnuts and cotton. Under these conditions, it becomes profitable for farmers in Regions 1, 2 and 3 to grow food as a cash crop. This is not normally the case in the model.

In Experiment 6 of the table, the modernization budget of Experiments 3 and 5 is allocated to the modernization of root food crops in Region 4. This run is characterized by a significant drop in the price of food and associated declines in value added and per capita income in Region 4. On the positive side, this experiment results in a substantial increase in per capita food consumption by the northern urban population.

In Experiment 7, the same modernization budget was allocated to the modernization of groundnuts, cotton and food grains grown in competition with these in the proportions 40 percent, 20 percent and 40 percent, respectively. Per capita incomes in Regions 1, 2 and 3 are uniformly higher than in Experiment 3 where these same resources are allocated to groundnuts and cotton alone. Foreign exchange earnings also show an increase over Experiment 3. Value added is depressed somewhat due to the reduced food price, the same effect noted in connection with Experiment 5.

Of the eight experiments summarized in Table 4.4, the last is the most favorable in its impact on the agricultural economy of northern Nigeria. In this run, the modernization budget of Experiments 3, 5, 6 and 7 is allocated to groundnuts and cotton in the ratio 2:1, as in Experiment 3. Augmenting this in Experiment 8 are marketing board price policies which substantially increase producer prices for groundnuts and cotton (as in Experiment 4). The results are large increases in all measures of performance, excluding marketing board surpluses which are zero under this policy option. The improvements are significantly more favorable than the direct sum of improvements from favorable marketing board price policies (Experiment 4) and modernization of groundnuts and cotton (Experiment 3) taken separately. The following data from Table 4.4 illustrates:

	Value added 1985
(a) Change in value added due to favorable marketing board policies alone. (Experiment 4 minus Experiment 1).	£ 62.8 million/year
(b) Change in value added due to modernization of groundnuts and cotton. (Experiment 3 minus Experiment 1).	£ 71.3 million/year
(c) Sum of (a) and (b)	£134.1 million/year
(d) Change in value added due to favorable marketing board policies <u>and</u> concurrent modernization of groundnuts and cotton. (Experiment 8 minus Experiment 1).	£219.7 million/year
(e) (d) minus (c)	£ 85.6 million/year

A final point to note in connection with Table 4.4 relates to the standard deviations associated with the outcomes of policy experiments. These relatively large values indicate that a wide range of outcomes is possible in any real-world development situation. A wide range of outcomes is possible, given the many random factors that influence results. Some may be more favorable than the mean or expected values and others may be less favorable.

The experiments of Table 4.4 are only a sample of the kinds of policy questions which should be addressed in connection with agricultural sector development in the northern region of Nigeria.

Further work should explore in more detail the effects of various levels of the modernization budget, different levels of marketing board off-takes (or subsidies)11/, different proportions of the modernization budget allocated to each commodity, etc. Further policy experiments for the purpose of aiding Nigerian planners would logically follow a critical review of the model--its structural assumptions and data--and a refinement phase which corrects defects encountered. This is not to say that useful insights cannot be gained from the model "as is," but one could proceed with more assurance after a thorough review.

11/ *Some work along these lines has been reported in Simulation Working Paper No. 70-2, March 31, 1970.*

TABLE 4.4
Results of Alternative Policy Experiments carried out with the Northern Regional Model—1985.

Experiment	Value added	Accumulated value added	Per capita nutrition (nonag.)	Food price	Foreign Exchange Earnings	Per capita cash income Region I	Per capita cash income Region II	Per capita cash income Region III	Per capita cash income Region IV	Marketing board surplus
	millions ₺/yr.	billions ₺/yr.	thousand calories/ year	₺/lb.	millions ₺/yr.	₺/person	₺/person	₺/person	₺/person	millions ₺/yr.
1. Standard--(no modernization and adverse marketing board policies)	634.8[a/] (121.9)[b/]	12.71 (1.431)	470.7 (76.09)	.0139 (.0030)	-73.9 (29.3)	2.584 (1.319)	3.319 (2.263)	2.577 (1.232)	37.96 (22.42)	16.02 (5.822)
2. Deterministic version of experiment #1 (parameters at most likely values)	539.3	11.10	610.8	.0100	-58.65	2.002	2.435	2.002	16.19	24.06
3. Groundnut and cotton modernization with adverse marketing board policies	716.1 (146.3)	13.26 (1.415)	467.4 (73.92)	.01414 (.0032)	-11.08 (52.76)	4.657 (2.719)	4.950 (3.161)	4.517 (2.218)	39.90 (24.39)	32.43 (13.54)
4. Favorable marketing board policies for groundnuts and cotton but no modernization programs	707.6 (137.4)	14.01 (1.615)	466.0 (75.86)	.01426 (.032)	-37.35 (43.44)	5.941 (3.983)	4.982 (2.955)	5.058 (2.539)	40.99 (24.45)	0
5. Food grain modernization with adverse marketing board policies	617.6 (120.4)	12.70 (1.401)	476.5 (76.01)	.01341 (.0029)	-58.23 (38.3)	3.278 (1.709)	4.7[illegible]8 (2.920)	3.267 (1.556)	34.66 (21.39)	20.02 (8.705)
6. Root food modernization with adverse marketing board policies	505.6 (126.2	12.00 (1.382)	544.8 (90.69)	.00914 (.0030)	-68.83 (27.89)	2.555 (1.414)	2.439 (1.292)	2.558 (1.298)	30.18 (13.43)	17.53 (5.806)
7. Modernization of groundnuts, cotton, and food grain with adverse marketing board policies	702.3 (130.1)	13.15 (1.423)	472.2 (76.67)	.01375 (.0029)	.227 (59.45)	5.126 (3.160)	6.015 (3.452)	5.041 (2.673)	37.00 (21.82)	35.38 (15.49)
8. Modernization of groundnuts and cotton with favorable marketing board policies	854.5 (170.9)	14.99 (1.766)	464.1 (76.72)	.014[illegible] (.0034)	[illegible]0.60 (98.21)	13.25 (10.10)	11.51 (7.421)	10.17 (5.90)	42.65 (25.91)	0

a/ Indicate means based on 100 simulation runs.   b/ ( ) indicate standard deviations based upon 100 simulation runs.

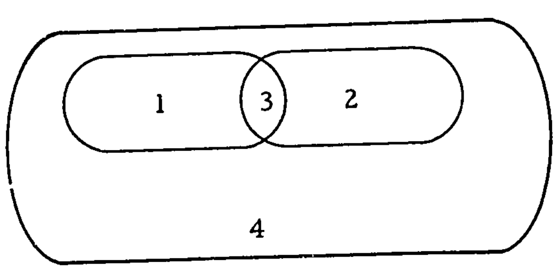
CHAPTER IV : APPENDIX
The Northern Model

THIS APPENDIX PRESENTS the various components of the Northern model in mathematical form. Included are the more important equations and assumptions; however, space does not permit a complete model description. The entire model is described in the computer program of the model. At certain points, the following description contains values for model parameters used in model tests. These are tentative, however, and are subject to change as better information becomes available.

The Land Allocation Component

The model views northern Nigeria as comprising four distinct ecological subregions. A Venn diagram of these four subregions appears in Figure 4.A.1.

The purpose of this component of the model is to simulate the behavior of northern Nigerian farmers in allocating cultivated lands to: (1) subsistence food; (2) cash food, i.e., food that sells in the cash market; (3) cash crops, i.e., groundnuts and cotton, within the appropriate subregion. For example, in Regions 1 and 2 the choice must be made between planting food for subsistence or for the cash market, or planting a cash crop.1/ The mathematical equations to follow describe the allocation mechanism between cash and noncash crops and then cash crops for Subregions 1 and 2, Subregion 3 and Subregion 4 in that order. This component allocates land on the basis of relative returns to labor from the competitive alternatives in each ecological subregion. It is thus responsive to marketing board prices for groundnuts and cotton (determined by policy and world prices) and food prices determined endogenously by the model as a whole.



1. Groundnut-food subregion
2. Cotton-food subregion
3. Groundnut-cotton-food subregion
4. Food only subregion

Figure 4.A.1. A Venn Diagram of the four ecological subregions of northern Nigeria.

1/ The area of each region can contract but not expand in the time span of the model.

Allocation Between Cash and Noncash Crops Within a ubregion

The acres of land allocatable to cash crops is computed by Equation (L1).

(L1) $AL_i(t) = LABA_i(t)*EAP_i(t)*APL_i(t)*PF_i(t)^{B_i}$

where:

AL_i = land allocatable to cash crops in Subregion i (i = 1,2,3,4)

$LABA_i$ = effective labor available (thousands of man-units) in Subregion i (computed in the population component)2/

EAP_i = proportion of the population in Subregion i that is active in producing cash crops (see Equation (L2))

PF_i = a profitability index for Subregion i (see Equation (L4))

APL_i = acres of cash crops cultivated per unit of labor at "normal" profitability (PF_i = 1) (see Equation (L3))

B_i = parameters that determine the magnitude of responses to profitability.

The variable EAP (computed in Equation (L2)) introduces the concept of an economically active population which includes those farmers who have responded to recently learned opportunities to start growing and selling on the cash market.

(L2) $EAP_i(t+DT) = EAP_i(t) + CL7_i*DT*(1 - EAP_i(t))$

where:

EAP_i = proportion of the population in Region i that is economically active $0 < EAP_i \leq 1$

$CL7_i$ = a model parameter that determines the rate at which farmers enter the economically active population

DT = the basic time increment used in the simulation.

This equation is a crude model of a diffusion process which gradually increases the economically active proportion over time. EAP will gradually approach 1 in the limit as time increases. The parameter $CL7_i$, which determines the speed of transition in each of the four regions, may be set at some constant value which approximates existing conditions or made dependent upon other variables such as extension programs, infrastructure developments, etc.

2/ The man-unit used in the model is one adult male in good health working 250 days per year in agricultural production.

The variable APL_i in Equation (L1) is an endogenous model variable computed by Equation (L3).

$$\text{(L3)} \quad APL_i(t) = MAX[APL_{oi}*CM_i - SFL_i(t)/LABA_i,\ 0]$$ [3/]

where:

APL_i = acres of cash crops per unit of labor in Subregion i (thousands)

APL_{oi} = total acres cultivatable per unit of labor in Subregion i at a given level of mechanization (thousands)

CM = a mechanization coefficient greater than or equal to one that introduces the effect of labor-saving investments (dimensionless)

SFL_i = land required for food self-sufficiency in Subregion i (thousands of acres) (see Equation (L5))

$LABA_i$ = total labor available in Region i--thousands of man-units

MAX[a,b] = a function that takes the maximum of the terms in brackets.

The profitability indices in Equation (L1) are determined as follows for Subregions 1 and 2 (groundnuts-food and cotton-food).

$$\text{(L4)} \quad PF_i(t) = \frac{(TLNF_i(t)*CR_i(t) + TLCF_i(t)*CRF(t))/AL_i(t)}{(TLNF_i(0)*CR_i(0) + TLCF_i(0)*CRF(0))/AL_i(0)}$$

where:

PF_i = profitability indices for Subregions 1 (i = 1) and 2 (i = 2)

AL_i = total land allocated to cash earners in Subregion i (thousands of acres)

$TLNF_i$ = total land in nonfood in Subregion i (thousands of acres)

$TLCF_i$ = total land in cash food in Subregion i (thousands of acres)

CR_i = net cash returns from nonfood in Subregion i (£/man-year)

CRF = net cash returns from cash food (£/man-year).

These indices are, simply, the weighted average of cash returns to labor in year "t" to those in year "zero"--the beginning year of the simulation. Similar equations compute profitability indices for Subregion 3, where cotton, groundnuts and food compete, and Subregion 4, where food is the only cash earner.

The model next computes the subsistence food land required in each region.

3/ It is assumed in this equation that acres cultivated per unit of labor are not significantly affected by modernization programs which may affect the labor inputs required per acre cultivated. The model could be revised to include this effect if necessary.

(L5) $SFL_i(t+DT) = SFL_i(t) + (DT/S3)*[(DEMR_i(t)/CALA_i(t)) - SFL_i(t)]$

This equation determines, after an adjustment lag S3, the amount of land SFL_i required to satisfy the regional rural demand for calories, $DEMR_i$, given that $CALA_i$ calories per acre are produced in Region i. Here again the index i ranges over the four regions included in the Northern model. $DEMR_i$, computed by the population component, is the total calorie requirement of farm families in Region i, plus or minus an adjustment factor that can account either for a planned surplus or a deficit.[4/]

Given the land required for food self-sufficiency and the land allocated to cash crops in each region, total cultivated land is:

(L6) $TL_i(t) = AL_i(t) + SFL_i(t)$

where:

AL_i = allocatable land in Region i (thousands of acres)

TL_i = total cultivated land in Region i (thousands of acres)

SFL_i = total land required for subsistence food in Region i (thousands of acres).

Cash Crops in Subregions 1 and 2

The model next allocates AL_1, AL_2, AL_3, and AL_4 to the competing cash crops in each region. It does this on the assumption that farmers will gradually move toward that crop which maximizes the net returns to labor.[5/] Land shifts to the more profitable crop at a rate that is proportional to:

1. The percent difference in cash returns per unit of labor that exists between the two crops,

2. The amount of land currently allocated to the less profitable crop,

3. A model parameter, CL1, which can be varied to match prevailing farmer behavior.

The equations that perform these functions for Subregions 1 and 2 are:

(L7) $R_i(t) = CL1*(CR_i(t) - CRF(t))*XTL_i(t)/(CR_i(t)) + DAL_i(t)/DT$

where:

R_i = the rate of change of nonfood land (thousand acres/year) for groundnuts (i = 1) and cotton (i = 2)

4/ *Currently the rural demand, $DEMR_i$, reflects the tendency of northern Nigerian farmers to be food self-sufficient. Any changes in this behavior pattern would be reflected in changes in the variable $DEMR_i$.*

5/ *This is reasonable in light of the fact that surplus land exists in most of northern Nigeria.*

CR_i = net cash returns per unit of labor (lagged to include behavioral effects) (£/man-year)

CRF = net food cash returns per unit of labor also lagged (£/man-year) (CR_1, CR_2, and CRF are computed by the production and marketing model component)

XTL_i = total allocatable land in cash food if $CR_i \geq CRF$

= total land in nonfood in Region i if $CR_i < CRF$

CL1 = a model parameter that controls the speed of land adjustment.

The variable DAL_i in Equation (L7) adds any net increase in allocatable land (AL_i) to the more profitable crop or subtracts any net decline from the less-profitable crop via Equation (L8).

(L8) $DAL_i(t) = MAX[(AL_i(t) - AL_i(t-DT)), 0]$, <u>if</u> $CR_i(t) \geq CRF(t)$

$= MIN[(AL_i(t) - AL_i(t-DT)), 0]$, <u>if</u> $CR_i(t) < CRF(t)$

Given the rate of change of nonfood land from Equation (L7), the model computes <u>total</u> nonfood land (in Regions 1 and 2) as:

(L9) $TLNF_i(t) = MAX[(TLNF(t-DT) + DT*R_i(t)), 0]$

This equation essentially computes the time integral of $R_i(t)$, limited to preclude the possibility of negative land.

To complete the land allocation for Regions 1 and 2, total cash food land is computed as a residual between total allocatable land, AL_i, and land allocated to nonfood production, $TLNF_i$.

(L10) $TLCF_i(t) = AL_i(t) - TLNF_i(t)$

Cash Crops in Subregion 3

The mechanism for allocating land to the three cash earners in Subregion 3 is similar to that above, though considerably more complex. In words, this part of the model gradually shifts land to the crop with the greatest return per unit of labor. Any net increase in land in Subregion 3 (due to price incentives, population growth, etc.) is added to the land in the most profitable crop. Any decreases in land over time are subtracted from the least profitable option if possible. If this is not possible, the decrement is subtracted from the second least profitable crop, and so forth. With three competitive crops there are six possible rankings with respect to profitability:

$CR(1) \geq CR(2) \geq CRF$

$CR(1) \geq CRF \geq CR(2)$

$CR(2) \geq CR(1) \geq CRF$

$CR(2) \geq CRF \geq CR(1)$

$CRF \geq CR(1) \geq CR(2)$

$CRF \geq CR(2) \geq CR(1)$

Here, CR(1), CR(2) and CRF are the current time-averaged cash returns (£/man-year) for groundnuts, cotton and cash food, respectively. The simulation model determines which of these six cases applies and then allocates land, beginning with the least profitable crop. The following equations apply:

(L11) $RJ3(t) = CL4*TLJ3(t-DT)*(CR3(t) - CR1(t))/CR3(t) + MIN[DAL_3(t), 0]/DT$

where:

RJ3 = rate of change of the least profitable crop in Region 3 (the joint region in which groundnuts, cotton and food are grown)--thousands of acres/year

TLJ3 = total land currently in the least profitable crop in Region 3 (thousand acres)

CR3 = cash returns for least profitable crop in Subregion 3 (£/man-year)

CR1 = cash returns for the most profitable crop in Subregion 3 (£/man-year)

CL4 = a model parameter that determines the speed of adjustment

MIN = the minimum operator.

The variable, DAL3, is the difference in allocatable land in Region 3 in the past time interval and is given by:

(L12) $DAL_3(t) = AL_3(t) - AL_3(t-DT)$

Given RJ3, the model computes a new value for TLJ3--the total land in the least profitable crop.

(L13) $TLJ3(t) = MAX[TLJ3'(t), 0]$

where:

$TLJ3'(t) = TLJ3(t-DT) + DT*RJ3(t)$.

Thus, Equation (L13) computes TLJ3 as the time integral of RJ3, limited to preclude the possibility of negative land.

The model then allocates land to the second least profitable crop. This, again, assumes that land shifts to the most profitable crop in proportion to differential profitabilities that exist. In addition, any net reduction in total land area in the region (DAL_3), that could not be removed from the least profitable crop, is taken out of this, the second least profitable crop. This behavior is described by the following equations:

(L14) $RJ2(t) = CL4*TLJ2(t-DT)*(CR2(t) - CR1(t))/CR2(t) + RESID(t)/DT$

where:

RJ2 = rate of change of the second most profitable crop (thousand acres/year)

TLJ2 = total land in the second most profitable crop (thousand acres)

CR2, CR1 = cash returns of second and most profitable crops, respectively (£/man-year).

(L15) $RESID(t) = MAX[MIN[TLJ3'(t), 0], MIN[DAL_3(t), 0]]$

where:

TLJ3', DAL_3 = defined in Equations (L12) and (L13).

(L16) $TLJ2(t) = MAX[TLJ2'(t), 0]$

where:

(L17) $TLJ2'(t) = TLJ2(t-DT) + DT*RJ2(t)$

Again, a constraint is imposed so that land area is non-negative. Land area in the most profitable crop, TLJ1, is computed simply as the residual between total allocatable land AL_3 and TLJ2 and TLJ3.

(L18) $TLJ1(t) = AL_3(t) - TLJ2(t) - TLJ3(t)$

Note that this equation allocates any net increase in allocatable land to the most profitable crop. Net decreases in AL_3, as described above, are removed from TLJ3 and TLJ2 if possible. If not, these latter areas are zero and the net decrease applies to TLJ1.

Given the total land areas according to each crop ranked by its profitability, the model then translates these into areas of groundnuts, cotton and cash food by applying the known profitability ranking which currently applies to the three crops. The following land areas are thereby defined:

TLJG(t) = total land in groundnuts in Subregion 3 (thousands of acres)

TLJC(t) = total land in cotton in Subregion 3 (thousands of acres)

TLJF(t) = total land in cash food in Subregion 3 (thousands of acres).

Cash Crops in Subregion 4

Land allocation in Subregion 4 (the food-only zone) is trivial, being simply the total allocatable land (if any) after the food needs of the regional population have been met.

(L19) $TLMBCF(t) = MAX(AL_4(t), 0)$

where:

TLMBCF = the total cash-food land in Subregion 4 allocated to cash food production (thousands of acres).

Totals of Food and Cash Crops for Northern Nigeria

With the above land allocations in the four subregions determined, it is a simple matter to compute total areas for northern Nigeria by crop. Total cash food land in the North, TCFLN, is given by:

(L20) $TCFLN(t) = TLCF_1(t) + TLCF_2(t) + TLJF_3(t) + TLMBCF(t)$

where:

$TLCF_1$, $TLCF_2$ = total land in cash food (Subregion 1 and 2) (thousands of acres)

$TLJF_3$ = total land in cash food (Subregion 3) (thousands of acres)

TLMBCF = total land in cash food (Subregion 4) (thousands of acres).

Total food land, ZLC1, is simply:

(L21) $ZLC1(t) = TCFLN(t) + SFL_1(t) + SFL_2(t) + SFL_3(t) + SFL_4(t)$

where:

SFL_i = the land required for food self-sufficiency in each subregion (Equation (L5)).

Total groundnut and cotton land, TGLN and TCLN, are computed as:

(L22) $TGLN(t) = TLNF_1(t) + TLJG(t)$

(L23) $TCLN(t) = TLNF_2(t) + TLJC(t)$

where:

$TLNF_1$, $TLNF_2$ = the total nonfood land in Subregions 1 and 2, respectively (thousands of acres)

TLJG = total groundnut land in Subregion 3 (thousands of acres)

TLJC = total cotton land in Subregion 3 (thousands of acres).

These commodity-specific land areas computed by the land allocation component are major inputs to the production and marketing component described in the following section.

The Production and Marketing Component

This subroutine, called AMP in the program, has important functions to fulfill within the entire system. It gathers information from most of the other subroutines and brings them together to perform several calculations. This subroutine is set up only once and the same set of equations applies for all crops of the northern region. An advantage of this subroutine is its relative simplicity and general character. The structure is such that it fits all annual crops under consideration, yet is flexible enough to meet specific needs of individual crops.

Each crop enters the subroutine with its own variables. A set of constant coefficients is defined for each particular crop. Many other variables are generated internally and vary over time. In this subroutine, six categories of computations are conducted:

1. Input and output relationships,
2. Wages and employment,
3. Utilization and distribution of products,
4. Farm income,
5. Taxation,
6. Values added to GNP and productivity measurements.

The input-output relationships are determined by the incoming land allocated to each crop (from the land allocation component), labor required and available for each crop, the level of yield and mechanization. The input-output relationships are computed below.

(P1) YLDD(t) = LND(t)*PY(t)

(P2) DEML(t) = (C_4*LND(t) + C_5*YLDD(t))/CM(t)[6/]

(P3) YLDL(t) = (CM(t)*LABA(t)/DEML(t))*YLDD(t)

(P4) YLD(t) = MIN(YLDD(t), YLDL(t))

<u>where</u>:

YLDD = total amount of the given commodity produced if PY reaches the biological maximum--thousand pounds/year

PY = yield per acre[7/] (pounds/acre-year)

LND = land allocated to a crop (thousands of acres)

DEML = total labor demanded for a crop[8/] (thousands of men)

LABA = labor actually available for a crop (thousands of men)

C_4 = labor requirements for cultivation (men/acre)

6/ Present usage of this subroutine in the Northern model equates demand for labor (DEML) to the supply (LABA). Labor constraints are introduced by the land allocation component, i.e., the variable (LND) in Equation (P1) is based on a labor constraint.

7/ PY is computed by the modernization component and is determined by production campaigns, diffusion effects, etc.

8/ Labor available and demanded is computed in units of adult men, working 250 days/year.

C_5 = labor requirements for harvesting (man-years/pound)

CM = a coefficient for mechanization, CM $\geq$ 1.--dimensionless

MIN(a,b) = a function that takes the minimum of terms in the parentheses.

YLDL = total production feasible as a function of labor available (thousand pounds/year)

YLD = total production actually achieved (thousand pounds/year).

Employment is calculated by crop for the agricultural sector (primary sector) and for the marketing sector.

(P5) EMP(t) = MIN(LABA(t), DEML(t))

(P6) EMPM(t) = C10*OUTP(t)

(P7) WAGESM(t) = WRM*EMPM(t)

(P8) WAGES(t) = EMP(t)*WR*C16

where:

EMP = men actually employed in production of the given crop (family and nonfamily labor) (thousand men)

MIN(a,b) = a function that takes the minimum of terms in parentheses

EMPM = employment provided by the marketing sector (thousand men)

OUTP = output actually marketed (see Equation (P16))

C10 = man-years per pound marketed

WAGESM = cash wages paid by the employers in the marketing sector (thousand £/year)

WRM = annual wage rate in marketing (£/man-year)

WAGES = wages paid by the agricultural sector to nonfamily labor (thousand £/year)

WR = annual wage rate in agriculture (£/man-year)

C16 = a constant determining the proportion of nonfamily labor (percent of EMP).

The utilization and distribution of the total output of one crop depend on the number and kinds of products derived from the primary product. Since all of the primary products go through similar stages of handling, storage and consumption with losses, conversion factors and change in product character involved, a rather generalized set of equations was developed to fit all crops under consideration. The following equations compute the primary and secondary products.

(P9) YLD1(t) = C1*C01*YLD(t)

(P10) YLD2(t) = C2*YLD(t)

(P11) YLD3(t) = C3*YLD(t)

where:

YLD 1, 2, 3 = products derived from YLD 9/

C01, C1, C2, C3 = constants (for a detailed definition and the values of the C- coefficients, see Tables 4.A.1 and 4.A.2).

(P12) OUT1(t) = C8*YLD1(t) 10/

(P13) OUT2(t) = C7*YLD2(t)

(P14) OUT3(t) = C6*YLD3(t)

where:

C6, C7, C8 = 1 minus proportion of losses involved so that OUT1, OUT2, OUT3, are the quantities of YLD1, YLD2 and YLD3 actually available for use.

The largest proportion of food crops and parts of groundnut production are consumed on the farm and do not enter the commercial market. This also represents the subsistence income paid in kind.

(P15) YLDW(t) = C14*EMP(t)*(1 - C16) 11/

(P16) OUTP(t) = C9*(YLD(t) - YLDW(t))

where:

YLDW = quantities consumed on the farm (subsistence income in kind) (thousand pounds/year)

C14 = quantities consumed by farm labor units (and dependents) (pound/man-year)

C16 = proportion of nonfamily labor (percent of EMP)

9/ See Table 4.A.1 for interpretations of these variables for the Nigerian setting.

10/ See Table 4.A.2 for interpretations of these variables for the Nigerian setting.

*11/ This relationship applies to cash crops such as groundnuts and cotton. If this component is used to simulate the production of a food crop, the following equation applies: YLDW = LSUB*PY where: LSUB is the land allocated to subsistence food.*

TABLE 4.A.1
Definition of Coefficients in the Marketing and Production Sector (Northern Region).

	Definition	Unit	Groundnut	Cotton	Food Regions 1-3	Food Region 4	Intermediate Output	Vari-able	Unit
C_{1a}[1/]	Proportion of net-yield (YLD) used for human consumption	%	.2	0.	1.	1.			
C_{1b}	Calories/unit	cal/lb.	1500	0.	1870	546.	Total calories	YLD1	1000 K Cal.
C_8	Amount of YLD1 available after storage (minus loss)	%	.9	0.	.9	.9	Calories avail. for consumption	OUT1	1000 K Cal.
C_{2a}[1/]	Proportion of net-yield (YLD) considered as grain residual	%	.05	.67	.20	.2			
C_{2b}	TDN/unit	%TDN	.7	1.	.7	.7	Total TDN grain residual	YLD2	1000 # TDN
C_7	Determines YLD2 available after storage (minus loss)	%	.9	.9	.9	.9	TDN available as grain residual	OUT2	1000 # TDN
C_3	TDN contained in leaves, rough forages, based on YLD	%TDN/acre	183.	183.	393.	393.	Total TDN rough forages	YLD3	1000 # TDN
C_6	Determining YLD3 available after storage (minus loss)	%	.3	.7	.7	.3	TDN available as rough forage	OUT3	1000 # TDN
C_9	Determines YLD reaching the commercial market (minus loss)	%	.9	.9	.7	.75	Net quantities handled on the commercial market	OUTP	1000 #
C_{10}	Required labor for trade marketing, transportation	man-year per lb.	.000045	.000045	.000045	.000022			
C_{11}	Determines OUTP consumed	%	.0	0.	1.	1.	OUTP consumed by non-rural people	OUTP1	1000 lb.
C_{12}	Determines OUTP exported	%	.7	.10	0.	0.		OUTP2	1000 lb.
C	Determines OUTP processed	%	.3	.90	0.	0.		OUTP3	1000 lb.
C	Proportion of non-family labor	%	0.	0.	0.	0.			

1/ Note: Model Parameter C_1 is equal to C_{1a} times C_{1b}, C_2 is equal to C_{2a} times C_{2b}.

TABLE 4.A.2
Other Coefficients and Initial Values in the Marketing and Production Sector (AMP)

	Labor requirements Cultivation (man-days/acre)	Harvesting	C4 man-year per acre	C5 man-year per lb.	PY[1/] Yield lb./acre
Maize	37	25			
Rice (irrigated)	153	47			
Millet	40	20			
Guinea Corn	40	20			
Cowpea	34	22			
Average Food Crop					
Regions 1-3	45	21	.11	.000052	595.
Region 4	69	22	.18	.000052	4520.
Groundnut	28	28	.11	.00016	595.
Cotton	20	20	.08	.0003	221.
Government (Cotton)	10	10	.04	.0001	400.
Soyabean	34	22	.14	.00026	335.

1/ Sources are:
CSNRD Report
FAO Report
Annual Abstracts of Statistics, Nigeria 1966
T. A. Philipp, An Agricultural Notebook

OUTP = quantity of the primary product available for the commercial market (thousand pounds/year)

C9 = 1 minus the proportion lost in marketing and transportation.

Quantities arriving on the commercial market are distributed between consumption by nonfarm people (OUTP1), export (OUTP2) and processing (OUTP3).

(P17) OUTP1(t) = C11*OUTP(t)

(P18) OUTP2(t) = C12*OUTP(t)

(P19) OUTP3(t) = C13*OUTP(t)

<u>where</u>:

C11, C12, C13 = constants defined in Table 4.A.1.

In order to calculate farm income, one needs prices for inputs and outputs. Wages, as a cost factor, are already defined in Equation (P8). The cost of other nonfarm inputs is computed in the modernization component and given to the production component as an exogenous variable. The producer price is derived from the marketing price on the assumption that the traders are in a relatively strong position compared to farmers. Therefore, the trader attempts to shift all burdens occurring from losses and taxes to the farmer. The following equations compute producer commodity price.

(P20) PP(t) = PM(t)*C9*(1. - TAXRM - PMAR)

(P21) TAXM(t) = MAX[0, TAXRM*((1 - C18)*PM(t)*OUTP(t)*PPRS(t) - WAGESM(t))]

where:

PPRS = proportion of output sold (less than 1 if aggregate demand is less than aggregate supply)

TAXM = tax to be paid by the trade sector (thousand £/year)

PP = producer price received by the farmer (£/pound)

PM = marketing price[12/] received by the trader (£/pound)

C18 = marketing overhead (proportion of total gross income exclusive of wages)

C9 = 1 minus proportion of output lost in marketing

TAXRM = tax rate to be paid from the traders' income (in percent)

PMAR = a profit margin held back by the trader (in percent).

The farmers' earnings are composed of a subsistence income paid in kind but evaluated at the producer price and normal cash payments for his sold products.

(P22) SUBI(t) = PP(t)*YLDW(t)

(P23) INCP(t) = PP(t)*(YLD(t) - YLDW(t))*PPRS(t)

where:

SUBI = subsistence income at producer price (noncash) (thousand £/year)

INCP = cash received by the farmers (thousand £/year)

PPRS = proportion of marketable product sold[13/]

YLDW = output consumed on farm--thousand pounds/year.

The farmers' total income and cash income then is given by:

12/ *The marketing prices for all nonfood cash crops are set by the marketing board. The food price is determined by demand and supply.*

13/ *In a situation in which excess supply exists in the market (cash food market in this case), only a proportion of output can be sold.*

(P24) FFGRI(t) = PP(t)*YLD(t) - WAGES(t) - CNFI(t)

(P25) FFCI(t) = INCP(t) - WAGES(t) - CNFI(t)

where:

FFGRI = total income from crop X (cash and kind payments) (thousand £/year)

FFCI = cash income from crop X (thousand £/year)

CNFI = cost of nonfarm inputs (thousand £/year).

The cash income, FFCI, is available for taxation, nonagricultural consumer goods, education and capital investments in factors of production.

The farmers' tax obligations are:

(P26) TAXP(t) = MAX[TAXRP(t)*FFCI(t), 0.]

leaving the agricultural production sector with a net cash income of:

(P27) PFTP(t) = FFCI(t) - TAXP(t)

where:

TAXP = tax to be paid by the agricultural sector from the earnings of crop X (thousand £/year)

TAXRP = tax rate imposed on the earnings of crop X within the production sector (percent)

PFTP = net cash income of the agricultural sector from crop X (thousand £/year).

The figures computed above are not calculated at the farm level but represent the contribution or earnings of a particular crop to the aggregated agricultural sector within one region.

The production and marketing subroutine also computes figures necessary for the national budget, e.g., value added in the production sector and value added in the marketing sectors. It also provides the necessary data for allocating land on the basis of financial returns to the factors of production, e.g., returns per unit of labor and returns per unit of land.

(P28) VAP(t) = PP(t)*YLD(t) - CNFI(t)

(P29) VAM(t) = OUTP(t)*PM(t)*PPRS(t) - INCP(t)

where:

VAP = value added to the production sector by crop X (thousand £/year)

VAM = value added to the marketing sector by crop X (thousand £/year).

The earnings of the factors of production labor and land are obtained by:

(P30) PFI(t) = YLD(t)*PP(t) - TAXP(t) - CNFI(t)

PFI can be defined approximately as a joint net income to labor and land combined. This amount, related either to land or labor, gives the returns per unit and is a measurement of productivity since not all costs are considered, e.g., capital cost, fixed assets, etc..

(P31) INMY(t) = PFI(t)/EMP(t)

(P32) RLRE(t) = PFI(t)/DEML(t)[14/]

(P33) RLND(t) = PFI(t)/LND(t)

where:

INMY = labor productivity actually achieved at the end of one year based on men employed (£/man-year)

RLRE = labor productivity for planning purposes based on labor required (£/man-year)

RLND = returns per acre (£/acre-year).

In the special cases where AMP is being used to simulate total food production--subsistence and for the cash market--alternative equations for (P31), (P32) and (P33) are necessary. This is because, for purposes of computing cash returns, the tax payments of (P26) are artifically low due to the subsistence food being considered. Correct equations for INMY, RLRE and RLND follow. In this case:

(P34) TAXPF(t) = MAX[TAXRP(t)*FFGRI(t), 0]

(P35) PFI(t) = YLD(t)*PP(t) - TAXPF(t) - CNFI(t)

and (P31), (P32) and (P33) apply with the PFI of Equation (P35).

If AMP is being used for commodities handled by a marketing board, such as groundnuts and cotton, the following equations permit the introduction of marketing board price policies and computation of marketing board revenues.

(P36) PMARBE(t) = (C10*WRM(t) - PM(t)*PPRS(t)*(TAXRM(t) - OHDM(t)))/PM(t)*PPRS(t)

where:

PMARBE = break-even margin for marketing boards--that proportion of total gross revenue that must be withheld from producers to cover marketing board costs

OHDM = marketing board overhead in excess of labor costs--proportion of gross revenue

14/ *The variables* $RLRE_{1,2,3}$ *are, respectively, the* CR_1, CR_2 *and CRF variables of the land allocation component.*

TAXRM = zero in this case.

(P37) PMAR(t) = PMARBE(t) + PMB(t)

where:

PMAR = total marketing board margin

PMB = marketing board margin above total marketing costs--a policy variable used to generate marketing board surpluses.

Recall that this variable, PMAR, is instrumental in establishing producer prices (see Equation (P20)).

(P38) MBREV(t) = OUTP(t)*PM(t)*PPRS(t)*(1 - OHDM(t)) - INCP(t) - WAGESM(t)

where:

MBREV = marketing board net revenue for the commodity in question--thousand £/year.

AMP also computes marketing board overhead, OHDMB, which is an input to the nonagricultural sector.

(P39) OHDMB(t) = OUTP(t)*PM(t)*PPRS(t)*OHDM(t)

The following equations (included in the executive program which calls AMP) complete computation of marketing board contributions to the northern economy as a whole.

MBREVA(t) = MBREVA(t) + DT*MBREV(t)

where:

MBREVA = accumulated revenue for the commodity in question--thousand £.

TMBREV(t) = $MBREV_1(t) + MBREV_2(t)$

where:

TMBREV = total marketing board revenue from the northern region--thousand £/year

$MBREV_1$ = revenue from groundnuts

$MBREV_2$ = revenue from cotton.

The Market Component

The primary purposes of this component are twofold:

1. To compute northern and southern food prices as functions of aggregate supply and demand in the two regions,

2. To compute interregional trade in food (if any) as a function of differential food prices and transport costs.

This component, therefore, provides a link between the Northern and Southern agricultural models. Mathematical details of this component are included in Chapter VIII where the interactions of major components of the national model are discussed.

The Modernization Component

The primary purpose of this component is to give the model the capability of exploring the impact of "packages" of modernizing inputs (improved seeds and practices, fertilizer and insecticide use, etc.) upon system behavior. The primary output of this component is an average productivity (yield/acre) that reflects the extent to which modernization has taken place for a specific commodity. This average productivity is an input to the production component, AMP.

In this component, the rate at which modernization takes place is determined by the following factors:

1. Profitability--no modernization takes place unless the net returns from modern practices significantly exceed those of traditional practices,

2. Government or other overt programs to introduce modern inputs,

3. Diffusion effects that propagate modern methods from farmer to farmer.

The simplifying assumption is made that seeds, fertilizer, pesticides, etc., are available and do not constrain the modernization process. The model does, however, compute demands for these inputs which reflect quantities necessary for modernization to proceed at the rate determined by the three factors cited earlier.

Following is a detailed description of the component, including the more important structural equations.

The profitability criterion influencing the rate of modernization is an exponentially time-averaged function of the relative (modern versus traditional) net returns to labor and is computed by Equation (M1).

$$\text{(M1)} \quad PC(t) = \frac{(PYM*PP(t) - PMB/E4 - PFRT*E143 - PCR*ESB - E18*CPL)/LABM}{PYT*PP(t)/LABT}$$

<u>where</u>:

PC = profitability criterion (not averaged over time)

PYM = average modern yield (pound/acre)

PYT = average traditional yield (pound/acre)

PP = current producer output price (£/pound)

E4 = the inverse of biological materials required per acre--acre/pound

PBM = price of biological materials (£/pound)

PFRT*E143 = value of fertilizer, pesticide, etc.--£/acre

PCR = price of credit--percent/year

ESB = a variable which in the absence of a subsidy is the credit required per year to sustain modern production (the model parameter E151). If, as a part of a production campaign, etc., a cash subsidy is granted, ESB becomes the residual credit requirement subject to interest changes (the model parameter E152)

LABM = labor required per acre with modern methods (men/acre)

LABT = labor required per acre with traditional methods (men/acre)

CPL = capital required per acre (modern)--£/acre

E18 = depreciation rate.

(M2) $$PCA(t) = PCA(t-DT) + DT*(PC(t) - PCA(t-DT))/DEL1$$

<u>where</u>:

PCA = exponentially averaged profitability criterion

DEL1 = a constant that determines the weight farmers give to past experience

DT = the time increment used in simulation (years).

Equations (M1) and (M2) apply to farmers' perceptions of the profitability of joining formal programs. i.e., government production campaigns, etc., which may be <u>subsidized</u>. Spontaneous adoption via diffusion may not be subsidized and, hence, the slightly different profitability criterion of Equation (M2.1) applies.

(M2.1) $$PCNS(t) = \frac{(PYM*PP(t) - PMB/E4 - PFRTM*E143 - PCR*E151 - E18*CPL)}{LABM*PYT*PP(t)/LABT}$$

Here PCNS is an <u>unsubsidized</u> profitability criterion. The only difference between this equation and (M1) is an unsubsidized fertilizer price (PFRTM) and an unsubsidized credit requirement (E151).

Equations (M1) and (M2.1) apply for the modernization of cash crops such as groundnuts, cotton and cash food grown in food-only regions of northern Nigeria. However, the modernization component is also used to introduce modern methods into food grown primarily for subsistence in the groundnut and cotton zones. In this case, a different profitability criterion is required, since farmers would be likely to view these improvements in light of the impact they would have upon their ability to grow more cash crops. The profitability criteria of Equations (M2.2) and (M2.3) apply in this case.

$$\text{(M2.2)} \quad PC_3(t) = \frac{PC_2(t)}{PC_1(t)}$$

$$\text{(M2.3)} \quad PCNS_3(t) = \frac{PCNS_2(t)}{PC_1(t)}$$

Here PC_3 is the profitability criterion for modernization of food grown in competition with cash crops, and $PCNS_3$ is the same variable without any external subsidies. Both these variables represent the ratio:

$$\frac{\text{net income per unit of labor (with food modernization)}}{\text{net income per unit of labor (without food modernization)}}$$

This is consistent with the criteria of Equations (M1) and (M2.1). In Equations (M2.2) and (M2.3) the following definitions apply:

$$\text{(M2.4)} \quad PC_1(t) = APL_3(t) * AVGRA(t)$$

$$\text{(M2.5)} \quad PC_2(t) = APL_3^1(t)(AVGRA(t) - PFRT_3(t)*E143_3 - PCR_3*ESB_3 - E18_3*CPL_3 - PBM_3(t)/E4_3)$$

$$\text{(M2.6)} \quad PCNS_2(t) = APL_3^1(t)(AVGRA(t) - PFRTM(t)*E143_3 - PCR_3*E151 - E18_3*CPL_3 - PBM_3/E4_3)$$

$$\text{(M2.7)} \quad APL_3(t) = MAX[APL_{o3}*CM_3 - SFL_3(t)/LABA_3(t)), 0]$$

$$\text{(M2.8)} \quad APL_3^1 = MAX[(APL_{o3}*CM_3 - \frac{SFL_3(t)*PYT_3}{LABA_3(t)PYM_3}, 0]$$

<u>where</u>:

APL_3 = acres of <u>cash crops</u>/unit of labor in groundnut-cotton-food regions of northern Nigeria (without food modernization)--See Equation (L3)

AVGRA = average gross returns per acre in this area (weighted average of groundnut, cotton and cash food returns)

APL_3^1 = acres of cash crops/unit of labor in groundnut-cotton-food regions of northern Nigeria <u>with</u> food modernization

APL_{o3} = total cultivated acres/man-unit in Region 3.

As seen from Equations (M2.7) and (M2.8) the average acres per unit of labor increase as a result of increased food yields (PYM_3).

The modernization component has been used in the Northern model to simulate the introduction of draught-animal type mechanization into the food-cash crop regions of northern Nigeria. This requires still another set of profitability criteria which are described below:

$$(M2.9)\quad PC(t) = LNDMCH*[AINCA_j(t) - CPL_j*E18(5)_j - COC_j + E141(5)_j*(1 - K3(5)_j) - PCR_j*ESB(5)_j]*LABNM/(LNDNM*AINCA(t)*LABMCH$$

$$(M2.10)\quad PCNS_5(t) = LNDMCH*[AINCA(t) - CPL_j*E18(5)_j - COC_j - PCR_j*E151(5)_j] *LABNM/(LNDNM*AINCA(t)*LABMCH)$$

<u>where</u>:

PC = subsidized profitability criterion for mechanization--dimensionless ratio of cash returns to labor with mechanization to cash returns to labor without mechanization

$PCNS_5$ = same as PC for the case of no subsidies

LNDMCH = cultivated land per acre with mechanization--acres/man

LNDNM = cultivated land per acre without mechanization--acres/man

LABMCH = labor input (men/acre) with mechanization

LABNM = labor input (men/acre) without mechanization

$AINCA_j$ = average gross income per acre in Region j--£/acre[15/]

CPL_j = capital requirements (mainly draught animals and associated equipment) in Region j--£/acre

$E18(5)_j$ = constant for maintenance and depreciation--dimensionless

COC_j = cost of operating capital--£/acre-year

$E141(5)_j$ = maximum cash subsidy paid (if any)--£/acre

$1 - K3(5)_j$ = proportion of maximum subsidy paid in Region j

PCR_j = interest rate--percent

$ESB(5)_j$ = credit requirement--£/acre in Region j.

The model is designed so that mechanization programs can be introduced into either or both of two subregions in northern Nigeria. The subscript, j, indices these two regions, which are:

15/ *This is a weighted average of gross income from crops in the relevant region (the groundnut-cotton-food grain region and the root crop region).*

1. The groundnut-cotton-food grain regions (Regions 1, 2 and 3 of Figure 4.A.1 of this appendix),

2. The root crop region (Region 4 of Figure 4.A.1).

These profitability criteria are instrumental in determining the rates at which farmers will respond in a diffusion process or to overt campaigns to introduce modern methods. We will first discuss the "production campaign" stream of modernization.

The rate at which land enters a modernization process, RLMPI, as a result of overt promotion, is given by Equation (M3).

(M3) RLMPI(t) = E3(t)*FPC1(t)*EXT1(t)

where:

EXT1 = units of precampaign promotion.16/ This, in general, will be a policy variable during simulation runs

E3 = the maximum feasible adoption rate per unit of EXT1 (acres/year per unit of EXT1)

FPC1 = a function which introduces the effects of the profitability criteria, PCA, upon the adoption rate.

The variable, FPC1, is given by Equation (M4) and is shown in Figure 4.A.2.

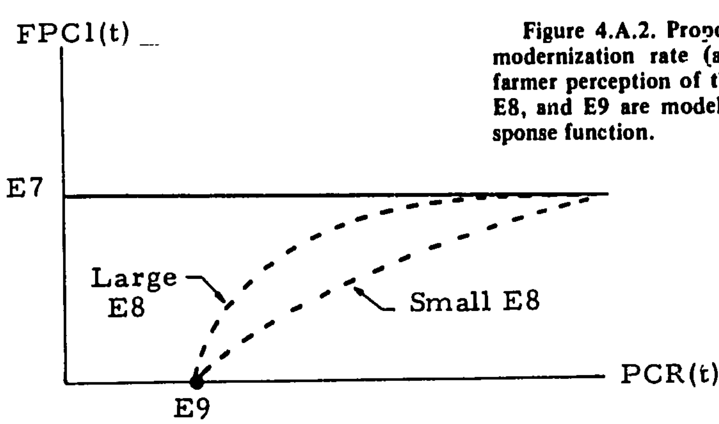


Figure 4.A.2. Proportion, FPC1(t), of the maximum feasible crop modernization rate (acres/year/unit of extension) as a function of farmer perception of the profitability of the new methods, PCR(t). E7, E8, and E9 are model parameters which govern the shape of the response function.

16/ *One interpretation of this variable would be the extension worker equivalents engaged in precampaign promotion. Another might be mass media units promoting adoption of the modern innovation.*

(M4) FPC1(t) = MAX(E7*(1 - EXP(-E8*(PCA(t) - E9))), 0)

where:

PCA = the relevant criterion measuring the farmers' perception of the profitability of the new methods

MAX(a,b) = a function equal to the maximum of terms within the parentheses

EXP = the exponential function

E7, E8, E9 = model parameters (see Figure 4.A.2).

As shown in Figure 4.A.2, the parameter E7 determines the maximum value of the function. E9 is a threshold below which no modernization can take place. The parameter E8 determines how rapidly the modernization rate changes with changes in the profitability criterion. It is clear that a wide range of adoptor behavior can be simulated by appropriately assigning values to these three parameters.

The variable E3 in Equation (M3) is computed as:

(M5) E3(t) = E31 - E32*EXP(-E33*TCAM(t))

where:

TCAM = the length of time the production campaign has been in operation--years

E31, E32, E33 = model parameters described below.

The purpose of this equation is to simulate the phenomenon that tends to make promotion easier and/or more efficient as the program progresses. Accordingly, E3 has its minimum value (E31 - E32) at the beginning of a campaign (TCAM = 0) and approaches its maximum value (E31) when TCAM is large. Again, a wide range of real-world situations can be simulated by appropriately assigning values to the model parameters.

The modernization process is simulated as a series of exponential delays which allow for the possibility of "dropouts" and represents the phenomena of random modernization times for individual farms in the aggregate. The equations which describe this process follow.

(M6) R1(t) = R1(t-DT) + DT(RLMPI(t) - R1(t-DT))/XDEL2

(M7) XR1(t) = R1(t)*A5

(M8) R2(t) = R2(t-DT) + DT(XR1(t) - R2(t-DT))/XDEL2

(M9) RLMP(t) = RLMP(t-DT) + DT(R2(t) - RLMP(t-DT))/XDEL2

where:

RLMPI = rate at which land enters the modernization process as a result of overt promotion--thousand acres/year

RLMP = average rate land leaves the modernization process and begins producing at "modern" levels--thousand acres/year

XDEL2 = one-third of the average time required for modernization--years

A5 = 1 minus the proportion of land that "drops out" due to shortage of technical assistance

R1, XR1, R2 = intermediate rates--thousand acres/year.

(M10) A5(t) = MIN(E12*EXTA(t)/EXTR(t), 1)

where:

EXTR = extension workers (or the equivalent) required to sustain the modernization program (thousands)

EXTA = extension workers available (thousands)

E12 = an adjustable model parameter

MIN(a,b) = the minimum of a and b.

As shown in Figure 4.A.3, the parameter E12 determines the threshold at which dropouts from the modernization process start and the dependence of the dropout rate upon the ratio EXTA/EXTR.

In order to compute inputs required for modernization, it is important to know how much land is in the modernization process at any given time. The land in modernization due to overt promotion is simply the time integral of RLMPI(t), minus the dropout rate, minus the rate land "completes" modernization. Equation (M11)

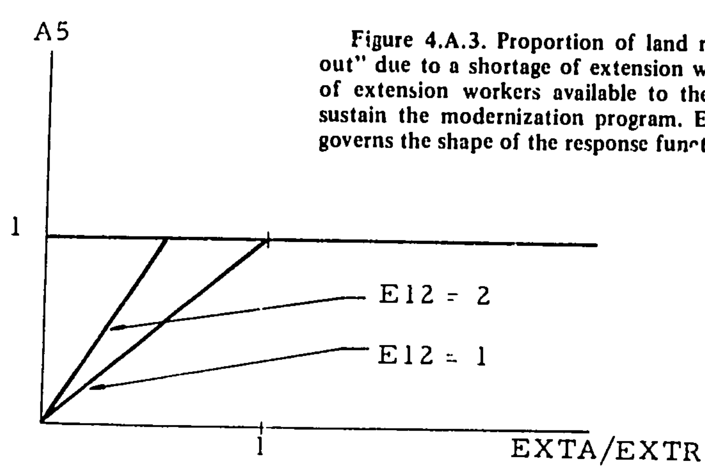


Figure 4.A.3. Proportion of land remaining, A5, after land "drops out" due to a shortage of extension workers. EXTA/EXTR is the ratio of extension workers available to the extension workers required to sustain the modernization program. E12 is a model parameter which governs the shape of the response function.

computes TRNSLE--the land in transition from traditional to modern practices due to overt (extension) promotion.

(M11) TRNSLE(t+DT) = TRNSLE(t) + DT(RLMPI(t) - RLMP(t) - (1 - A5)*R1(t))

The model also computes the total land which has been modernized as a result of overt production campaigns, ZLMZD, as:

(M12) ZLMZD(t+DT) = ZLMZD(t) + DT*RLMP(t)

We now turn our attention to the simulation of modernization that takes place spontaneously--by diffusion from farmer to farmer.

The rate land "enters" a modernization process, RLMDI, as a result of diffusion is given by:

(M13) RLMDI(t) = FPC2(t)*(TRADL(t) - TRNSLE(t) - TRNSLD(t))*ZMODL(t)/ALTOTI

where:

TRADL = total land in traditional production (for the crop undergoing modernization)--thousand acres

ZMODL = total land in modern production--thousand acres

TRNSLE, TRNSLD = total land in modernization due to overt promotion and diffusion, respectively--thousand acres

ALTOTI = total land allocated to the commodity in question at the beginning of the simulation run--thousand acres

FPC2(t)[17] = MAX[E10*(1 - EXP(-E8 (PCNS - E9))), 0.]--a function (similar to FPC1 of Figure 4.A.2) which introduces profitability as a determinant of the diffusion rate

MAX(a,b) = the maximum of a and b.

This equation requires further explanation. Due to the nature of the function FPC2, adoption of modern methods by diffusion will only take place if the profitability of modern practices significantly exceeds that of traditional methods. Further, the rate of adoption is determined in part by the differential between modern and traditional productivities. The diffusion rate is also a function of:

$$\frac{\text{(Traditional land-land in modernization)*Modern land}}{\text{Total land}}$$

The term in parentheses is the land which, as yet, has not adopted modern practices. Ceteris paribus, one would expect the diffusion rate to be proportional to this variable. Inclusion of modern land as a multiplicative factor is one way of

17/ *The profitability criterion used in computing FPC2 will be an unsubsidized one. See Equations (M2.1), (M2.3) and (M2.10).*

introducing demonstration effects. With no modernized land there is no demonstration effect and no diffusion. As modern land increases, demonstration effects increase and, ceteris paribus, the diffusion rate increases. The total land in the denominator is a normalizing factor. Evidence in support of the validity of this formulation of the diffusion process is the fact that it produces an "s" shaped adoption curve similar to many that have occurred in practice.

The rate land enters modern production, RLMD, as a result of diffusion is the output of a three-stage delay process similar to that of Equations (M6, M8 and M9).

(M14) R3(t) = R3(t-DT) + DT*(RLMDI(t) - R3(t-DT))/XDEL3

(M15) R4(t) = R4(t-DT) + DT*(R3(t) - R4(t-DT))/XDEL3

(M16) RLMD(t) = RLMD(t-DT) + DT*(R4(t) - RLMD(t-DT))/XDEL

where:

R3, R4 = intermediate rates

RLMDI = rate land enters modernization as a result of diffusion--thousand acres/year

RLMD = rate land enters modern production as a result of diffusion--thousand acres/year

XDEL3 = one-third of the delay involved in modernization--years.

In this case, there are no "dropouts" due to a possible shortage of technical assistance (extension agents, etc.). This is due to the fact that technical assistance is available from farmers already using modern methods. On the other hand, the delay inherent in modernization by diffusion may be longer than that of an overt "production campaign."

Given RLMD from Equation (M16), it is possible (and necessary) to compute TRNSLD, the land in transition (from traditional to modern production) as a result of the diffusion process.

(M17) TRNSLD(t+DT) = TRNSLD(t) + DT*(RLMDI(t) - RLMD(t))

It is also important in the model to simulate any "dropouts" that occur if the profitability of modern methods should drop significantly due to declining output prices, increasing input prices, etc. In this case, farmers using modern methods may revert to traditional practices. This dropout rate is the product ZMODL(t)*FPC3(t),

where:

ZMODL = the total land in modern production

FPC3 = proportion of total land in modern production which reverts to traditional practice (see Equation (M18)).

(M18) FPC3(t) = MAX(E11*(1 - EXP(-E81*(E91 - PCNS(t)))), 0)

where:

PCNS = the relevant nonsubsidized profitability criteria of Equations (M2.1), (M2.3) or (M2.10)

E11, E81, E91 = model parameters.

This function is shown in Figure 4.A.4.

It is clear that if the profitability criteria relating modern returns to traditional returns (PCNS) is greater than some threshold value, E91, FPC3 is zero and there are no dropouts from modern production. For smaller values of PCNS, FPC3 is some positive number between zero and E11, indicating that some percentage of the modern land reverts to traditional methods annually. Again, the model parameters (E91, E81 and E11) can be selected to simulate a range of real-world conditions.

Given this dropout rate and the rates land is being modernized by production campaigns and diffusion, it is possible to compute the total modern land, ZMODL, which is assumed to produce at modern productivities.

(M19) ZMODL(t+DT) = ZMODL(t) + DT*(RLMP(t) + RLMD(t) - ZMODL(t)*FPC3(t) + E6 *ZMODL(t)*RALTOT(t)/ALTOT(t))

where:

RLMP = rate land enters modern production from production campaigns--thousand acres/year

RLMD = rate land enters modern production as a result of diffusion--thousand acres/year

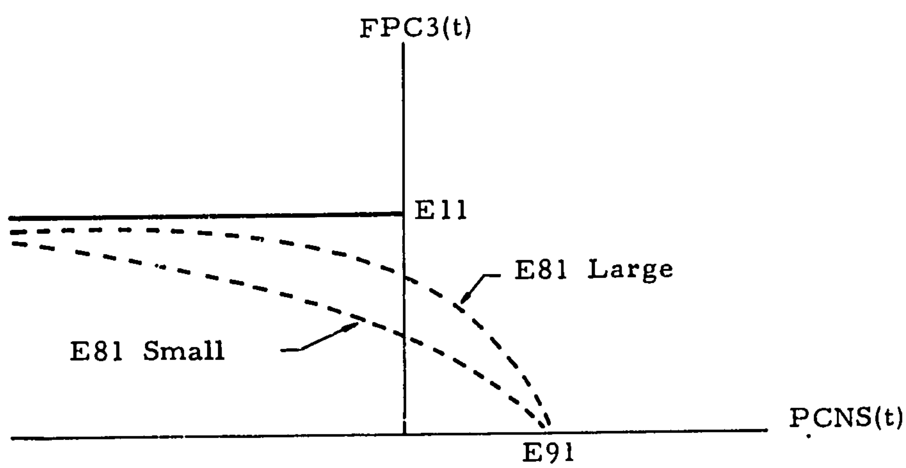


Figure 4.A.4. Proportion of total land in modern production which reverts to traditional practice, FPC3(t), as a function of the nonsubsidized profitability criterion, PCNS(t)

ZMODL(t)*FPC3(t) = rate land "drops out" of modern production due to low profitability

RALTOT = rate of change of total land in the given commodity

ALTOT = total land in the given commodity

E6 = a model parameter that determines the percentage of land entering or leaving the given commodity that enters or leaves modern production.

The inclusion in Equation (M19) of the term involving "RALTOT" requires further discussion. It is clear that, over time, the total land allocated by decision makers to a given commodity will change. The question arises--how should these changes be allocated to traditional and modern production? The model formulation permits the user to make a number of assumptions about this through adjustment of the parameter E6. For example, if E6 = 0, the model allocates all increases or decreases in total land to traditional production. If E6 = 1, the model allocates changes in land areas to traditional and modern production proportionally according to the percentage each is of total land. Further, if:

$$E6 = 1 \quad \text{for} \quad RALTOT \geq 0$$

$$E6 = 0 \quad \text{for} \quad RALTOT < 0$$

the model allocates net increases in total land proportionally to modern and traditional production and subtracts all decreases from traditional production, etc.

To continue with the main stream of the component description, land allocated to traditional production, TRADL, is readily computed as:

(M20) TRADL(t) = ALTOT(t) - ZMODL(t)

where:

ZMODL = land in modern production as computed above

ALTOT = total land allocated to the commodity in question (an input variable to this component computed by the land allocation component).

In order to compute an average productivity for the given commodity (the primary function of this model component), we compute total output, OTOT, as:

(M21) OTOT(t) = PYM*ZMODL(t) + PYT*TRADL(t)

where:

PYM, PYT = modern and traditional productivities per acre, respectively

(M22) PYAVG(t) = OTOT(t)/ALTOT(t)

where:

PYAVG = average productivity

ALTOT = total land allocated to the given commodity.

The remaining equations of the modernization component compute demands for the various modernizing inputs.

(M23) DEEX2(t) = E5(t)*TRNSLE(t)

where:

DEEX2(t) = production campaign demand for technical assistance (measured in thousands of extension worker equivalents)

TRNSLE = land in transition due to overt promotion--thousand acres

E5 = extension worker equivalents per acre in transition (provision is made in the model for this requirement to change over time to simulate learning effects, etc.).

(M24) DBMAT(t) = E13*ZMODL + (TRNSLE(t) + TRNSLD(t))/E4

where:

DBMAT = demand for biological materials (seeds, etc.)--thousand pounds

E13 = pounds of biological material required per acre of modernized land

E4 = acres/pound of biological material for land in transition from traditional to modern practices.

(M25) DFERT(t) = E141*TRNSLE(t) + E142*TRNSLD(t) + E143*ZMODL(t) + E144*TRADL(t)

where:

DFERT = total demand for fertilizer--thousand pounds

E141, E142, E143, E144 = per acre requirements--pounds/acre.

(M26) EXTI(t) = E16*DBMAT(t) + E17*DFERT(t)

where:

EXTI = thousand men required to distribute inputs[18/]

E16, E17 = man-units/unit of biomaterial and fertilizer.

(M27) DCRDT(t) = ESB*(TRNSLE(t) + TRNSLD(t) + ZMODL(t))

18/ *This variable makes it possible to assess the impact of alternative strategies regarding the use of extension personnel in the distribution of inputs.*

where:

ESB = per acre credit requirement defined in Equation (M1)

DCRDT = total demand for credit to sustain modernization working credit and credit for capital investment.

(M28) DINV(t) = CPL*(XR1(t) + R3(t)) + E18*CAP(t)

where:

DINV = demand for capital investment

CPL = capital requirements per acre (to sustain modern production)--£/acre

XR1 = lagged[19] rate land enters modernization process due to production campaigns--thousand acres/year

R3 = lagged[19] rate land enters modernization process due to diffusion effects--thousand acres/year

CAP = total value of existing (modernizing) capital--thousand £

E18 = depreciation factor.

Assuming that demand for capital inputs is satisfied, the total value of modernization capital for the given commodity is computed as:

(M29) CAP(t+DT) = CAP(t) + DT*CPL*(XR1(t) + R3(t))

Finally, the component computes the total cost of nonfarm inputs (CNFI) for use elsewhere in the overall model.

(M30) CNFI(t) = PFRT(t)*DFERT(t) + DINV(t)

This concludes description of the major model structural relationships. The modernization component is used replicatively, once for each commodity in the Northern model, and whenever mechanization is introduced as a modernization alternative. Unfortunately, inherent differences between the nature and economics of annual and perennial production preclude the possibility of directly using this component in modeling the southern tree crop economy. Tests of this model have led to informative insights into the interrelationships between overt efforts to stimulate modernization (production campaigns, etc.) and spontaneous diffusion processes. It is quite clear that, under favorable conditions (profitability and availability of modernizing inputs), a burst of overt promotion can provide a "trigger" for a spontaneous diffusion process.

19/ The lag here accounts for the fact that demand for capital equipment will lag the decision to adopt modern methods (see Equations (M7) and (M14)).

The Consumption and Budgeting Component of the Northern Model

This component converts from commodity to regional accounts and computes disposable income and other relevant variables on a regional basis within the Northern model. In order to convert from commodity to regional accounts, factors must be computed which reflect the proportion of each commodity grown in each region. A description of these computations follows. These equations assume that crop yields for a given commodity are uniform across regions.

(CB1) $P1G(t) = TLNF_1(t)/TGLN(t)$

(CB2) $P1F(t) = (SFL_1(t) + TLCF_1(t))/ATL_3(t)$

where:

P1G = proportion of total groundnuts grown in Region 1 (groundnuts-food)

P1F = proportion of total food grain[20/] grown in Region 1

$TLNF_1$ = total nonfood (groundnut) land in Region 1--thousand acres

TGLN = total groundnut land--thousand acres

SFL_1 = total subsistence food land in Region 1--thousand acres

$TLCF_1$ = total cash food land in Region 1--thousand acres

ATL_3 = total land allocated to food grains (in competition with groundnuts and cotton)--thousand acres.

In like manner, the model computes the proportions of total cotton and food grain produced in Region 2 (cotton-food).

(CB3) $P2C(t) = TLNF_2(t)/TCLN(t)$

(CB4) $P2F(t) = (SFL_2(t) + TLCF_2(t))/ATL_3(t)$

The following equations compute the proportions of total groundnuts, cotton and food grains produced in Region 3--the ecological zone of northern Nigeria in which groundnuts, cotton and food grains all compete for land.

(CB5) $P3G(t) = TLJG(t)/TGLN(t)$

(CB6) $P3C(t) = TLJC(t)/TCLN(t)$

(CB7) $P3F(t) = (SFL_3(t) + TLJF(t))/ATL_3(t)$

(CB7) $P3F(t) = (SFL_3(t) + TLJF(t))/ATL_3(t)$

20/ *This is food that grows in competition with groundnuts and cotton and excludes food, dominantly root crops in the Middle Belt, that does not do so.*

where:

P3G, P3C, P3F = proportion of total groundnut, cotton and food grain grown in Region 3

TLJG = total groundnut land in Region 3--thousand acres

TLJC = total cotton land in Region 3--thousand acres

TGLN = total groundnut land--thousand acres

TCLN = total cotton land--thousand acres

SFL(3) = subsistence food grain land in Region 3--thousand acres

TLJF = cash food grain land in Region 3--thousand acres

ATL_3 = total land allocated to food grains--thousand acres.

As will be seen later, it is also necessary to compute, by regions, the proportion of food grains sold in the market. These proportions, P1FC, P2FC and P3FC are computed as follows:

(CB8) $P1FC(t) = TLCF_1(t)/TLCFNN(t)$

(CB9) $P2FC(t) = TLCF_2(t)/TLCFNN(t)$

(CB10) $P3FC(t) = TLJF(t)/TLCFNN(t)$

where:

$TLCF_1$, $TLCF_2$ = total land in cash food production in Regions 1 and 2--thousand acres

TLJF = total land in cash food production in Region 3--thousand acres

TLCFNN = total land in cash food in Regions 1, 2, 3--thousand acres.

Given these regional proportions, it is possible to convert incomes, costs of inputs and credit requirements (which the production-marketing component computes on a commodity basis) to a regional basis.

Farm income (including credit) by regions within northern Nigeria is computed as follows:

(CB11) $FINC_1(t) = P1G(t)*(INCP_1(t) + DCRDT_1(t)) + P1FC(t)*INCP_3(t) + DCRDT_3(t) *P1F(t) + DCDTMN(t)*TL_1(t)/TLNN(t)$

(CB12) $FINC_2(t) = P2C(t)*(INCP_2(t) + DCRDT_2(t)) + P2FC(t)*INCP_3(t) + DCRDT_3(t) *P2F(t) + DCDTMN(t)*TL_2(t)/TLNN(t)$

(CB13) $FINC_3(t) = P3G(t)*(INCP_1(t) + DCRDT_1(t)) + P3C(t)*(INCP_2(t) + DCRDT_2(t)) + P3FC(t)*INCP_3(t) + DCRDT_3(t)*P3F(t) + DCDTMN(t)*TL_3(t)/TLNN(t)$

(CB14) $FINC_4(t) = INCP_4(t) + DCRDT_4(t) + DCDTMM(t)$

where:

$FINC_i$ = gross farm income for Region i--thousand £/year, i = 1,2,3,4

$INCP_j$ = gross producer income generated by crop j,21/ j = 1,2,3--thousand £/year

$DCRDT_j$ = demand for credit by commodity--thousand £/year (j = 1,2,3)

DCDTMN = demand for credit to support a mechanization program in Regions 1, 2 and 3--thousand £/year

DCDTMM = demand for credit to support a mechanization program in the Middle Belt (Region 4) thousand £/year

TL_i = total land planted in Region i, i = 1,2,3,4--thousand acres

TLNN = total land planted in Regions 1, 2 and 3--thousand acres.

The model allows for possible multiplier effects in regional income due to regionally produced and consumed goods and services such as home building, small implement manufacturing and repair, etc. The variables, $TFINC_i$, represent these multiplied regional incomes and are computed as:

(CB15) $TFINC_i(t) = FINC_i(t)/(1 - CMUL_i)$

where:

$FINC_i$ = regional farm incomes--thousand £/year

$CMUL_i$ = proportion of total income in Region i spent for goods and services produced in Region i, i = 1,2,3,4.

Regional credit demands, $RDCDT_i$, are computed as:

(CB16) $RDCDT_1(t) = P1G(t)*DCRDT_1(t) + P1F(t)*DCRDT_3(t) + DCDTMN(t)*TL_1(t)/TLNN(t)$

(CB17) $RDCDT_2(t) = P2C(t)*DCRDT_2(t) + P2F(t)*DCRDT_3(t) + DCDTMN(t)*TL_2(t)/TLNN(t)$

(CB18) $RDCDT_3(t) = P3G(t)*DCRDT_1(t) + P3C(t)*DCRDT_2(t) + P3F(t)*DCRDT_3(t) + DCDTMN(t)*TL_3(t)/TLNN(t)$

21/ *j = 1 for groundnuts, 2 for cotton and 3 for food grains.*

(CB19) $RDCDT_4(t) = DCRDT_4(t) + DCDTMM(t)$

As part of the regional accounts, this model component computes the debt and debt service by regions. Regional debt service is computed by the following equation:

(CB20) $NDS_i(t) = MAX[CDS_i(t)*NDBT_i(t), 0] \quad i = 1,2,3,4$

<u>where</u>:

NDS_i = the debt service paid by Region i--thousand £/year

$NDBT_i$ = the total agricultural indebtedness in Region i--thousand £

CDS_i = a debt service coefficient determined by policy (this coefficient is roughly the proportion of the debt paid annually).

This formulation permits the model user to experiment with alternative repayment schedules through the debt service coefficient CDS.

The total indebtedness by regions is computed as the time integral of credit received minus debt service. In the model, this is accomplished by:

(CB21) $NDBT_i(t+DT) = NDBT_i(t) + DT*(RDCDT_i(t) - NDS_i(t)) \quad i = 1,2,3,4$

<u>where</u>:

$NDBT_i$ = the debt in Region i--thousand £

$RDCDT_i$ = the credit received in Region i--thousand £/year

NDS_i = debt service payments in Region i--thousand £/year

Regional interest changes, $RINT_i$, are computed as the interest rate times the indebtedness.

(CB22) $RINT_i(t) = PCR_i*NDBT_i(t) \quad i = 1,2,3,4$

<u>where</u>:

PCR_i = regional price of credit (interest rate).

In order to complete regional accounting and compute revenue flows to the nonagricultural model, we must compute the payments for nonfarm inputs to agricultural production. The following equations compute, by regions, the farm costs of chemical and capital inputs to agricultural production in northern Nigeria. We begin by computing the total cost of chemical inputs (dominantly fertilizer) by <u>commodity</u>.

(CB23) $CNFICH_j(t) = PFRT_j(t)*DFERT_j(t) \quad j = 1,2,3,4$

<u>where</u>:

$CNFICH_j$ = cost of nonfarm chemical inputs for commodity j--thousand £/year

$PFRT_j$ = farm price of chemical inputs for commodity j-- £/pound

$DFERT_j$ = demand for fertilizer and other chemicals for the j^{th} commodity-- thousand pound/year.

Regional costs of chemical inputs, $RINCCH_i$, are computed by:

(CB24) $RINCCH_1(t) = P1G(t)*CNFICH_1(t) + P1F(t)*CNFICH_3(t)$

(CB25) $RINCCH_2(t) = P2C(t)*CNFICH_2(t) + P2F*CNFICH_3(t)$

(CB26) $RINCCH_3(t) = P3G(t)*CNFICH_1(t) + P3C(t)*CNFICH_2(t) + P3F(t)*CNFICH_3(t)$

(CB27) $RINCCH_4(t) = CNFICH_4(t)$

Total farmer payments for chemical inputs, (TFPMTN) are simply:

(CB28) $TFPMTN(t) = \sum_{i=1}^{4} RINCCH_i(t)$

The model assumes that chemical demand is satisfied, either by the industrial sectors of the economy, or by imports.

Regional expenditures for production capital, $RINCC_i$, are computed by the following equations:

(CB29) $RINCC_1(t) = P1G(t)*TDINV_1(t) + P1F(t)*TDINV_3(t) + CCMN(t)*TL_1(t)/TLNN(t)$

(CB30) $RINCC_2(t) = P2C(t)*TDINV_2(t) + P2F(t)*TDINV_3(t) + CCMN(t)*TL_2(t)/TLNN(t)$

(CB31) $RINCC_3(t) = P3G(t)*TDINV_1(t) + P3C(t)*TDINV_2(t) + P3F(t)*TDINV_3(t)$

$+ CCMN(t)*TL_3(t)/TLNN(t)$

(CB32) $RINCC_4(t) = TDINV_4(t) + CCMM(t)$

where:

$RINCC_i$ = total regional demands (i = 1,2,3,4) for capital investment-- thousand £/year (i = 1,2,3,4)

$TDINV_j$ = demands for capital investment by commodity (excluding mechanization demands)--thousand £/year (j = 1,2,3,4)

TL_i = total planted land in Region 1--thousand acres (i = 1,2,3)

TLNN = total planted land in Regions 1, 2 and 3--thousand acres

CCMN = total capital investment for mechanization programs in Regions 1, 2 and 3--thousand £/year

CCMM = total capital investment for mechanization programs in Region 4 (the Middle Belt)--thousand £/year.

Total northern agricultural demand for capital inputs is computed as:

$$\text{(CB33)} \quad CAPDP(t) = \sum_{i=1}^{4} RINCC_i(t)$$

This variable is an input to the nonagricultural model. It is assumed that this demand is satisfied by the industrial sectors of the economy or by imports.

Given these expenditures on farm inputs together with gross incomes ($TFINC_i$), the model computes producer taxes (if any) paid by region.

$$\text{(CB34)} \quad RTAXN_i(t) = TAXRP_i(t)*(TFINC_i(t) - RINCC_i(t) - RINCCH_i(t))$$

where:

$FTAXN_i$ = taxes paid by producers in the i^{th} region--thousand £/year

$TAXRP_i$ = producer tax rate for the i^{th} region (dimensionless).

Total producer taxes, TPTAXN, are given by:

$$\text{(CB35)} \quad TPTAXN(t) = \sum_{i=1}^{4} TAXRP_i(t)$$

To proceed toward our goal of computing disposable income for nonagricultural sector consumption, we compute consumption within agricultural producing regions for miscellaneous items such as home construction, implement repair, personal services, etc.--items within the agricultural sector normally not included in national accounts. This regional consumption is denoted $RCIN_i$ and is computed as:

$$\text{(CB36)} \quad RCIN_i(t) = CMUL_i(t)*TFINC_i(t) \qquad i = 1,2,3,4$$

where:

$TFINC_i$ = the total income in Region i --thousand £/year

$CMUL_i$ = the proportion spent on such goods and services.

We are now in a position to compute disposable income by producing regions. This income becomes expenditures for consumer goods and services and is an important revenue flow to the nonagricultural model. This is computed on the assumption that there is a minimum level of per capita consumption expenditure for each region, $CMINPC_i$, and that credit is supplied, if necessary, to meet these consumption levels. Disposable income may be less than minimum consumption levels when production modernization programs are being implemented. In these cases, the model computes additional credit required in order to sustain the modernization programs and provide for minimum levels of consumption expenditure.

We begin by computing regional disposable income in the absence of supplemental credit (ADUM).

(CB37) $ADUM_i(t) = TFINC_i(t) - RINCCH_i(t) - RINCC_i(t) - NDS_i(t) - RTAXN_i(t)$

$- RCIN_i(t) - RINT_i(t)$

<u>where</u>:

$TFINC_i$ = total farm income in Region i--thousand £/year

$RINCCH_i$ = expenditure on chemical inputs in Region i--thousand £/year

$RINCC_i$ = expenditure on capital inputs in Region i--thousand £/year

NDS_i = debt service in Region i--thousand £/year

$RTAXN_i$ = tax payments in Region i--thousand £/year

$RCIN_i$ = consumption of regionally produced goods and services not included in national accounts--thousand £/year

$RINT_i$ = interest payments in Region i--thousand £/year.

Next, we compute minimum consumption level by region.

(CB38) $CMIN_i(t) = CMINPC_i(t)*POPAGR_i(t) \quad i = 1,2,3,4$

<u>where</u>:

$CMIN_i$ = minimum level of consumption of goods from the nonagricultural economy in Region i--thousand £/year

$CMINPC_i$ = minimum level of per capita consumption of goods from the nonagricultural economy in Region i--£/person -year (This variable is currently fixed during a given simulation run. Further consideration should be given to making this an endogenous model variable.)

$POPAGR_i$ = total agricultural population in Region i--thousand persons.

Actual agricultural disposable income for expenditure in the nonagricultural sector, $RDIN_i$, is:

(CB39) $RDIN_i(t) = MAX[ADUM_i(t), CMIN_i(t)]$

where $ADUM_i$ and $CMIN_i$ are given by Equations (CB37) and (CB38). In the event that disposable income, $ADUM_i$, is less than minimum consumption, $CMIN_i$, additional credit is acquired and the regional debt is correspondingly increased to make consumption at the level of $CMIN_i$ possible. The following equations apply:

(CB40) $ARDCDT_i(t) = RDCDT_i(t) + CMIN_i(t) - ADUM_i(t)$

where:

$ARDCDT_i$ = augmented credit in Region i--thousand £/year

$RDCDT_i$ = credit in Region i before augmentation--thousand £/year

$CMIN_i$, $ADUM_i$ = as defined by (CB37) and (CB38).

(CB41) $ANDBT_i(t+DT) = NDBT_i(t+DT) + DT*(CMIN_i(t) - ADUM_i(t))$

where:

$ANDBT_i$ = augmented debt in Region i--thousand £/year (this variable is used in the computation of $NDBT_i$ in the following time period--on the right side of Equation (CB21))

NDBT = nonaugmented debt in Region i--thousand £/year.

Total agricultural production disposable income, TAGDIP (the consumption variable sent to the nonagricultural model), is obtained by summing $RDIN_i$ across regions.

(CB42) $$TAGDIP(t) = \sum_{i=1}^{4} RDIN_i(t)$$

This particular model component also computes total disposable income from agricultural marketing that goes into consumption from the nonagricultural sector (TAGDIM).

(CB43) $$TAGDIM(t) = OHDMB_1(t) + OHDMB_2(t) + CN1*[WAGESM_1(t) + WAGESM_2(t)] + CN2 *[VAM_3(t) - TAXM_3(t) + VAM_4(t) - TAXM_4(t)]$$

where:

$OHDMB_1$, $OHDMB_2$ = marketing board overhead for groundnuts and cotton, respectively--thousand £/year

$WAGESM_1$, $WAGESM_2$ = wages paid for marketing of groundnuts and cotton, respectively--thousand £/year

VAM_3, VAM_4 = value added from marketing food grains in competition with groundnuts, cotton and food in the Middle Belt, respectively--thousand £/year

$TAXM_3$, $TAXM_4$ = taxes paid from marketing of the two food types--thousand £/year

CN1 = proportion of groundnut and cotton marketing wages spent on nonagricultural goods

CN2 = proportion of cash food value added (less taxes) spent on nonagricultural goods.

The component also computes other variables. Some of these provide additional necessary linkages with the nonagricultural model and others provide supplemental criteria of relevance to decision making.

Specifically, the model computes total agricultural production and marketing taxes in northern Nigeria, $TAXAG_1$.

(CB44) $TAXAG_1(t) = TAXMT(t) + TPTAXN(t)$

where:

TAXMT = total taxes from marketing (exclusive of marketing board revenues)--thousand £/year

TPTAXN = total producer taxes (see Equation (CB35) of this component).

Additionally, the model computes the total cash expenditure on fertilizer and other chemicals (a variable needed in the nonagricultural model). This variable, $VALCP_1$, differs from TFPMTN in Equation (CB28) in that it is based on market price of fertilizer and not the farm price which may be subsidized. (TFPMTN is based on farm fertilizer prices.)

(CB45) $VALCP_1(t) = \sum_{i=1}^{4} PFRTM_j(t)*DFERT_j(t)$

where:

$PFRTM_j$ = price of fertilizer for the j^{th} commodity--£/pound

$DFERT_j$ = demand for fertilizer for the j^{th} commodity--thousand pounds/year.

Finally, this component computes gross per capita income, RPC_i, for the four regions of northern Nigeria. As a means to this end, FIN_i, gross income in Region i excluding credit received, is computed as:

(CB46) $FIN_1(t) = P1G*INCP_1(t) + P1FC(t)*INCP_3(t)$

(CB47) $FIN_2(t) = P2C(t)*INCP_2(t) + P2FC(t)*INCP_3(t)$

(CB48) $FIN_3(t) = P3G(t)*INCP_1(t) + P3C(t)*INCP_2(t) + P3FC(t)*INCP_3(t)$

(CB49) $FIN_4(t) = INCP_4(t)$

(CB50) $RPC_i(t) = FIN_i(t)/((1 - CMUL_i(t))*POPAGR_i(t))$

where:

$INCP_j$ = income (thousands of pounds/year) from the j^{th} commodity

$CMUL_i$ = the regional multiplier

$POPAGR_i$ = the regional population.

Beef-Milk Production Component

The beef-milk component was the first developed during the simulation project. Its purpose was to simulate cattle production in northern Nigeria and alternative means of improving it. The component is a complete model in its own right, containing an executive program which applies improvements to the traditional and (hypothetical) modern cattle populations of the regions.

Subroutine DEMOG

Using subroutines it was possible to simulate the behavior of both traditional and modern animal populations over time with one general model. Subroutine DEMOG performs this function in the beef-milk production component of the Northern model.

A subroutine of a program is to the model what a subsystem is to a system. It can be viewed as receiving certain inputs from the system model and supplying outputs which, in turn, are inputs to the system model. In the case of subroutine DEMOG, the primary inputs (from the Northern model) are:

TDNA = total digestible nutrients per animal (tons/animal-year)

SF, SM = sales of females and males, respectively, per year (thousand animals/year)

A number of parameters which determine birthrates, death rates, time delays, etc.

RFT, RMT = rate at which females and males are transferred from traditional to modern production sectors.

The primary outputs supplied by this subroutine are:

PF, PM = population of females and males, respectively (thousand animals)

DF, DM = deaths of females and males, respectively (thousand animals/year)

ER = extraction ratio (percent offtake) feasible at the given level of nutrition without changing population size.

An important attribute of this subroutine is that, given a set of inputs, a corresponding set of outputs will be computed. In this case, if "traditional" or "modern" inputs are supplied, "traditional" or "modern" outputs, respectively, will be computed. Thus, one subprogram can be used to simulate two or more subsystems which are alike in structure but differ in input and parameter values. This same concept was used repeatedly in developing the total model of which this component is a small part. In what follows, equations are numbered with a prefix indicating the component to which they relate.

Equation (BF1) of subroutine, DEMOG, computes the live birthrate as a function of level of nutrition.

(BF1) BR(t) = B41*TABLIE(VALB, SMALLB, DIFFB, KB, TDNA(t))

where:

BR = live birthrate--proportion of all females calving per year

TABLIE = a simulation subprogram which approximates arbitrary[22/] functional relationships by straight line segments

VALB = an array of numbers which defines the dependent argument of the function

TDNA = total digestible nutrients (tons per animal-year)--the independent argument of the function

SMALLB = smallest value of TDNA in the data which defines the function

DIFFB = the fixed difference between values of TDNA

KB = the number of line segments used to approximate the birthrate function

B41 = a model parameter (nominally one) which can be used to shift the birthrate function up or down.

Since birthrates in the traditional and modern sectors are different functions of TDNA due to different environmental conditions and management practices, the model includes the two birthrates versus TDNA functions shown in Figure 4.A.5(a,b). Equation (BF1), therefore, defines traditional or modern birthrates depending upon whether VALB is supplied with traditional or modern data. The data in Figure 4.A.5(a,b) are rough estimates based on available literature and conversations with animal scientists familiar with Fulani animals.

In like manner, Equation (BF2) computes traditional and modern herd death rates as a function of nutritional levels.

(BF2) DR(t) = B42*TABLIE(VALD, SMALLD, DIFFD, KD, TDNA(t))

where:

DR = death rate--proportion of total population dying per year

VALD = an array defining the dependent argument

TDNA = total digestible nutrients (tons per animal-year)

SMALLD, DIFFD, KD = as defined in Equation (BF1)

B42 = a parameter (nominally one) which can be used to shift the death rate function up or down.

Important in establishing this functional relationship is the concept of "maintenance TDN" or the level of nutrition required to maintain weight but no growth. Below this level of nutrition, starvation rapidly ensues and the death rate rapidly increases.

22/ *This subprogram is a table-look-up algorithm which interpolates linearly between data points (Llewellyn, 1965).*

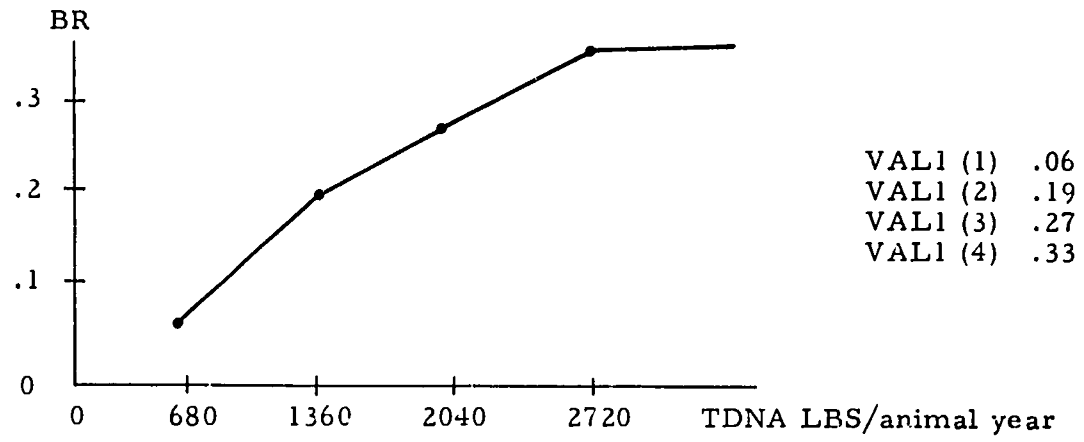


Figure 4.A.5.a. Traditional birth rate versus total digestible nutrients.

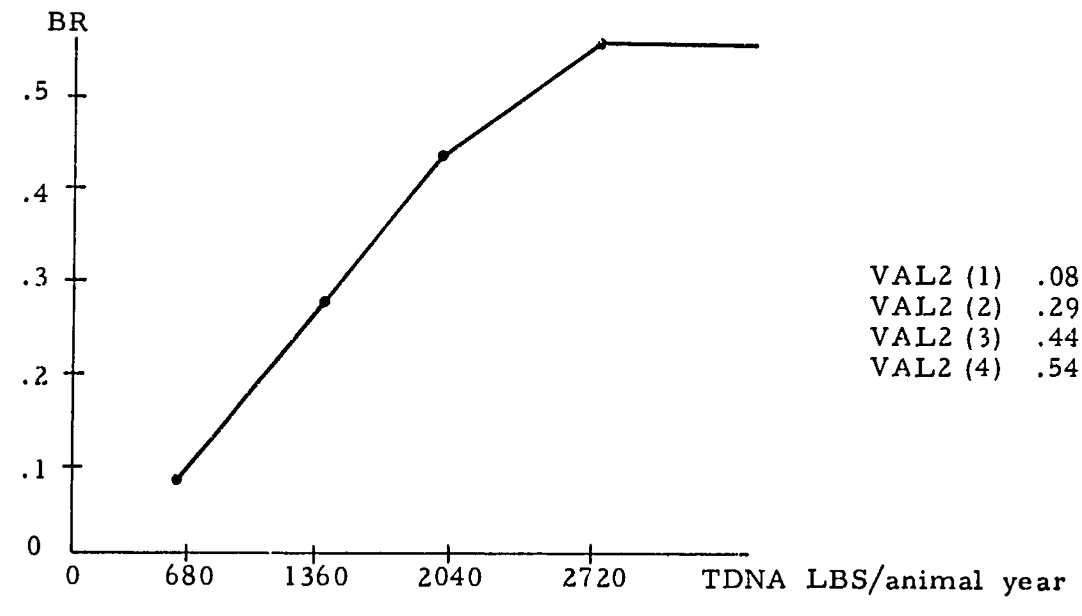


Figure 4.A.5.b. Modern birth rate versus total digestible nutrients.

In the model, a herd average level of maintenance TDN was calculated from estimates of maintenance TDN for various ages of Fulani cattle and data on the age distribution of Fulani cattle. The resulting herd average for maintenance was 1,360 pounds of TDN per animal-year. The death rate curves of Figure 4.A.6(a,b) were developed in consultations with knowledgeable animal scientists.

Equation (BF3) of subroutine DEMOG computes the extraction ratio or "offtake" feasible at various levels of nutrition.

(BF3) ERP(t) = PF(t)*BR(t)/(PF(t) + PM(t)) - DR(t)[23/]

where:

ERP = unlagged extraction ratio--proportion of herd that can be removed annually without changing herd size

PF, PM = number of herd females and males

BR, DR = birth and death rates as defined above.

Equation (BF3) is derived by finding the sales rate that will exactly balance the excess of herd births over deaths and dividing this rate by the total herd population.

In reality, births, deaths and extraction ratios do not change instantaneously with changes in nutritional levels and/or population sizes, but rather lag behind changes in these variables. The variables BR, DR and ERP must, therefore, be modified to introduce these lag effects. Equation (BF4) computes the auxiliary variable A1 used in a later computation related to the birthrate lag.

(BF4) A1(t) = BR(t)*PF(t)

where:

A1 = total live births/year--thousand animals/year

BR = proportion of all females yielding live calves per year

PF = population of females--thousand animals (recall that this subroutine can apply to either the traditional or modern herd).

In the case of animal births, introduction of an appropriate lag is somewhat more complicated than for deaths and extraction ratios. This is due to the fact that a natural increase in female population does not influence the calving rate for several years, but a natural decrease in population has a much more rapid influence (a delay approximating the gestation period). This difference in delay, depending upon whether the population is increasing or decreasing, is accounted for by Equations (BF5) through (BF10). Equation (BF5) computes an exponential average of A1.

(BF5) A1P(t+DT) = A1P(t) + (DT/.3)*(A1(t) - A1P(t))

23/ This equation is based upon the assumption that male and female death rates are the same. Subsequent consistency runs of the model indicated that female death rates must exceed male death rates.

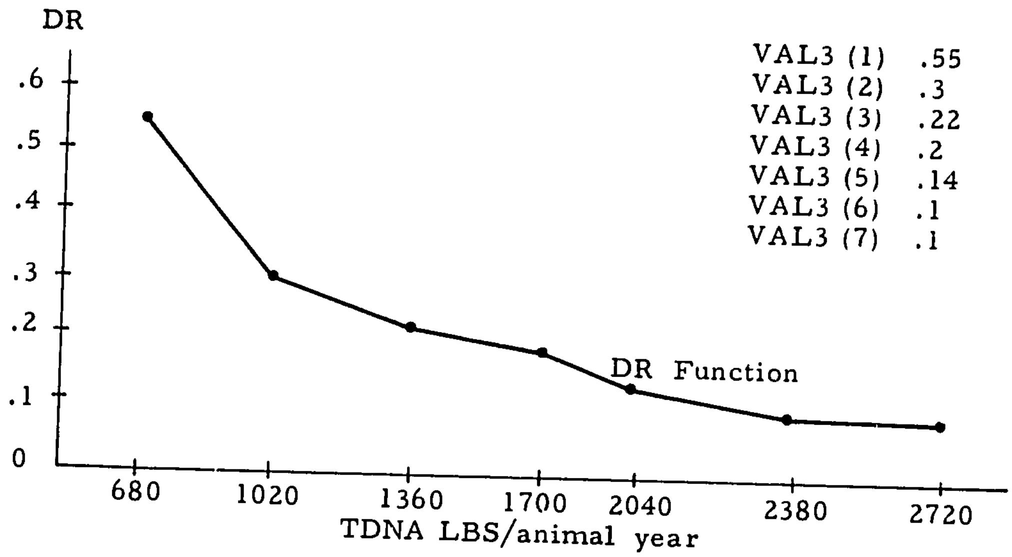


Figure 4.A.6.a. Traditional death rate versus total digestible nutrients.

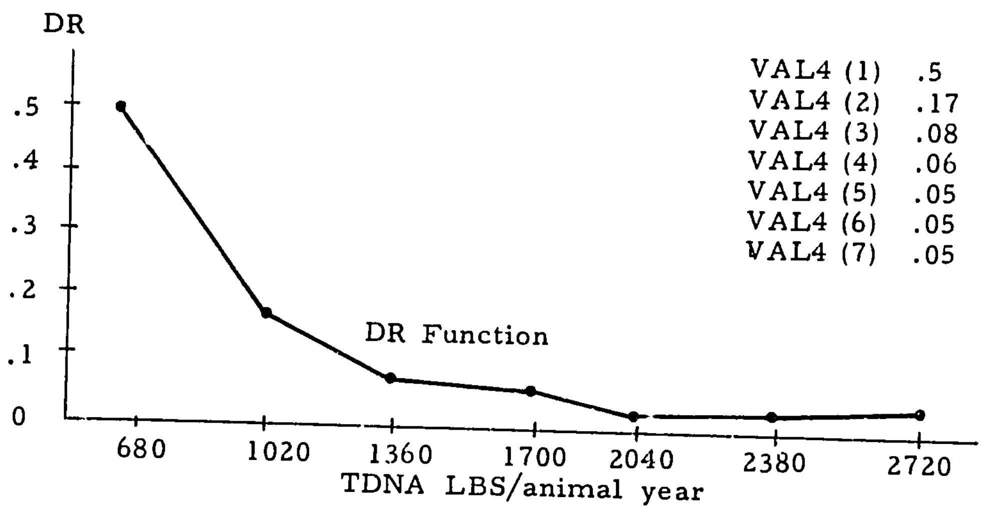


Figure 4.A.6.b. Modern death rate versus total digestible nutrients.

where:

A1P = an exponential average of A1

DT = time increment used in the simulation

A1 = as computed in Equation (BF4).

Note that the variable (A1 - A1P) is proportional to the derivative dA1/dt and, therefore, has the same sign as the rate of change of A1. Equations (BF6) through (BF9) of the subroutine assign one value (D1) to the delay if (A1 - A1P) is negative and a larger value (D2) if this quantity is zero or positive. Finally, Equation (BF10) computes A2, which is a lagged version of A1. (The lag here is first order exponential.)

(BF10) A2(t+DT) = A2(t) + (DT/BRDEL)*(A1(t) - A2(t))

where:

A2 = live births delayed (thousand animals/year)[24/]

DT = time increment of the model

BRDEL = D1 for (A1 - A1P) $\leq$ 0

= D2 for (A1 - A1P) > 0

A1 = unlagged live births.

It is assumed in the model that births are evenly distributed between males and females. Equations (BF11) and (BF12) compute BF and BM as 0.5*A2 where BF and BM are, respectively, the female and male births per year. Equations (BF13) through (BF17) compute the actual (lagged) deaths of females and males, DR and DM, and the lagged extraction ratio, ER.

(BF13) A3(t) = PF(t)*DR(t)

(BF14) DF(t+DT) = DF(t) + (DT/D3)*(A3(t) - DF(t))

(BF15) A4(t) = PM(t)*DR(t)*B40

(BF16) DM(t+DT) = DM(t) + (DT/D4)*(A4(t) - DM(t))

(BF17) ER(t+DT) = ER(t) + (DT/D5)*(ERP(t) - ER(t))

where:

PF = population of females (thousand animals)

24/ *More precisely, this technique should be applied to the variables PF and BR separately. The assumption implicit here is that the lag effects due to PF and BR are identical.*

PM = population of males (thousand animals)

DR = unlagged death rate

DF = female deaths (thousand animals/year)

DM = male deaths (thousand animals/year)

ER = actual extraction ratio

ERP = unlagged extraction ratio

B40 = a parameter (less than 1) to account for the fact that male death rates are generally lower than female death rates

D3, D4, D5 = lag parameters--years.

The next two equations of subroutine DEMOG compute, respectively, the number of animals in the female and male populations as time integrals of population flow rates.

(BF18) PF(t+DT) = PF(t) + DT*(BF(t) - DF(t) - SF(t) - RFT(t))

where:

PF = population of females (thousand animals)

BF = female births per year (thousands)

DF = female deaths per year (thousands)

SF = female sales per year (thousands)

RFT = rate females are transferred from the traditional sector to modern grazing reserves (thousand animals/year).

(BF19) PM(t+DT) = PM(t) + DT*(BM(t) - DM(t) - SM(t) - RMT(t))

where:

PM = population of males (thousand animals)

BM = male births per year (thousands)

DM = male deaths per year (thousands)

SM = male sales per year (thousands)

RMT = rate males are transferred from the traditional sector to modern grazing reserves (thousand animals per year).

It can be seen that Equations (BF18) and (BF19) are discrete numerical approximations to the continuous integrals which determine PF and PM.

Consistency Checks

In a demographic model, certain relationships exist between the birthrates, death rates, sales rates, sex ratios, sales sex ratios, theoretical extraction rates, actual extraction rates and herd size growth. In the following development of internal consistency checks, these definitions are used.

BR = proportion of total females calving

DRM, DRF = proportion of males that die and proportion of females that die, respectively

SR = population of males divided by population of females

ERT = proportion of the total herd that may be sold, keeping the total population constant

PM, PF = population of males and females, respectively

SM, SF = sales of males and females, respectively.

Assuming the population of males and females is unchanged through time, the following equations hold:

$$\frac{dPF(t)}{dt} = (BR(t)/2)*PF(t) - DRF(t)*PF(t) - SF(t) = 0$$

$$\frac{dPM(t)}{dt} = (BR(t)/2)*PF(t) - DRM(t)*PM(t) - SM(t) = 0$$

The extraction ratio is defined as:

$$ER(t) = \frac{SM(t) + SF(t)}{PF(t) + PM(t)}$$

Solving for SM and SF in the first two equations and substituting into the third gives:

$$ER(t) = \frac{(BR(t)/2)*PF(t) - DRF(t)*PF(t) + (BR(t)/2)*PF(t) - DRM(t)*PM(t)}{PF(t) + PM(t)}$$

This reduces to:

$$ER(t) = \frac{BR(t)*PF(t) - DRF(t)*PF(t) - DRM(t)*PM(t)}{PF(t) + PM(t)}$$

Dividing by PF gives:

$$ER(t) = \frac{BR(t) - DRF(t) - DRM(t)*SR(t)}{1 + SR(t)}$$

This is the equation of the theoretical extraction ratio that can be compared with the extraction ratio calculated by the program. If the herd size is increasing, the extraction ratio of the model should be lower than the theoretical one. Conversely, if the herd size is decreasing, the model extraction ratio should be higher than the theoretical one.

Another test was developed to check the consistency of the sex ratio of sales with assumed birthrates, death rates for males and females and the sex ratio. The sales sex ratio is defined as $\frac{SM}{SF + SM}$. Solving the first two equations again for SM and SF, and substituting into the sales sex ratio gives:

$$\text{Sales sex ratio} = \frac{\frac{BR(t)}{2}*PF(t) - DRM(t)*PM(t)}{\frac{BR(t)}{2}*PF(t) - DRF(t)*PF(t) + \frac{BR(t)}{2}*PF(t) - DRM(t)*PM(t)}$$

Dividing by PF gives:

$$\text{Sales sex ratio} = \frac{\frac{BR(t)}{2} - DRM(t)*SR(t)}{\frac{BR(t)}{2} - DRF(t) + \frac{BR(t)}{2} - DRM(t)*SR(t)}$$

Simplifying the denominator yields:

$$\text{Sales sex ratio} = \frac{\frac{BR(t)}{2} - DRM(t)*SR(t)}{BR(t) - DRF(t) - DRM(t)*SR(t)}$$

Checking the extraction ratios and the sales sex ratio with the data given by others indicated that the death rate for females must be higher than the death rate of males. This seems reasonable since the age distribution of the females is older and they encounter more stress than males due to calving and nursing. Therefore, the death rate for females was taken to be 1.7 times the death rate of males in later simulation runs.

The Master Beef-Milk Simulation Program

This section will describe the structure of the simulation program which controls the operation of subroutine DEMOG, provides for the introduction of alternative modernization policies, generates output data and performs other executive functions. Discussion will begin with a description of policy options which are presently built into the model. Certain others can be included as the need arises.

Policy Variables

At the beginning of each simulation run, certain modernization policies are established and the model then generates the consequences through time. The model is constructed so that a number of simulation runs can be processed sequentially. Equation (BF22) allocates new crop land to cash crops and animal feed crops and provides means of comparing returns to beef-milk versus returns to cash crops. (The expansion of food crop land in the model is determined in the land allocation component.)

(BF22) RLC3(t) = RLTT(t) - B17(t)

where:

RLC3 = rate at which land is transferred to animal feed crops (thousand acres/year)

RLTT = rate at which land (within the beef-milk sector) is transferred from grazing land to cash and feed crops (thousand acres/year)

B17 = a policy parameter less then RLTT--the rate at which land is transferred to cash crops (thousand acres/year).

The assumption is made here that cash and animal feed crops compete for a limited amount of land (RLTT) converted annually to one or the other of these enterprises.

Expenditures on fly eradication and grazing reserve development are introduced as policy variables by Equations (BF23) and (BF24).

(BF23) EFE(t) = B18(t)

(BF24) EXGR(t) = B19(t)

where:

EFE = expenditure on fly eradication (thousand pounds/year)

EXGR = capital expenditures on grazing reserves (thousand pounds/year)

B18 = a policy parameter (thousand pounds/year)

B19 = a policy parameter (thousand pounds/year).

The following equations introduce herd management policies through control of sales rates.

(BF25) SFT(t) = PFT(t)*(B20 + ELAS1*SFT(t)*(PA(t) - PAO)/(PFT(t)*PA(t))) + BSFT

*(PFT(t) - TDNT(t)/((1. + B22)*TDNTAR(t)))[25]

(BF26) SMT(t) = B21*(PMT(t) - B22*PFT(t)) + B35*PMT(t)

where:

SFT = sales of females in the traditional sector (thousand animals/year)

SMT = sales of males in the traditional sector (thousand animals/year)

PFT, PMT = population of females/males in the traditional sector (thousand animals)

25/ The first term of this equation is derived from a supply curve of the form SFT = PFT(B20 + C*(PA - PAO)) and application of the definition of supply elasticity. (C here is a constant proportional to the supply elasticity.)*

TDNT = total TDN available for traditional animals (thousands of pounds of TDN per year)

TDNTAR = "target" level of TDN (pounds per animal-year)

ELAS1 = the price elasticity of supply

PA = price of animals (pounds/head)

PAO = "normal" price of animals (This is the value of price about which linearization of the supply curve took place.)

B22 = desired sex ratio--ratio of males to females

B20, B21, B35, BSFT = parameters which permit exploration of alternative sales policies.

These policies were designed with flexibility to permit simulation of the current behavior of Fulani tribesmen and exploration of alternative policies. Equation (BF25) describes a positively sloped supply curve. Current parameters allow only little supply response, which appears consistent with limited available data. The second term of this equation permits the user of the model to explore the impact of population control schemes designed to maintain some desired level of animal nutrition (the variable TDNTAR). If the model parameter, BSFT, is set greater than zero, this population control mechanism is operative. Equation (BF26) permits control of the sex ratio by making male sales a function of the difference (PMT - B22*PFT), the parameter B22 (a number between 0-1) being the desired ratio of males to females. Sales vary in proportion to this difference and tend through time to establish the desired sex ratio, B22. (The fact that Fulani herds are approximately 70 percent female and 30 percent male suggests that herdsmen have, in fact, attempted to control the male proportion of the herd.) Response to price is implicit in Equation (BF26) since female sales changes on the basis of price changes will induce changes in male sales through the sex ratio adjustment mechanism described above. More direct male price response can be added to the model if desired. Similar relationships exist for management of the modern herd.

Animal price, PA, is taken as an exogenous variable as defined by Equation (BF27).

(BF27) PA(t) = PAO*(1 + B33*T + B34*SIN(6.2816*T))

<u>where</u>:

PAO, B33, B34 = constants

T = time.

This equation makes possible the investigation of effects of secular and seasonal changes in animal price. The model does not currently generate beef prices as endogenous variables. The work of Kellogg (1971) has developed demand relationships for Nigerian beef. It is a straightforward matter to bring supply and demand relationships together to compute endogenous prices, if desired, in a more detailed study of the beef industry.

Grazing Reserves Program

Equations (BF28), (BF29) and (BF30) compute the grazing land area in modern grazing reserves in response to a policy that allocates funds to grazing reserve development.

(BF28) AUX3(t) = EXGR(t)*B2

where:

EXGR = capital expenditures on grazing reserves (thousand pounds/year)

B2 = acres modernized per pound of capital expenditures (or equivalently thousand acres per thousand pounds since the units in the model are thousand acres and thousand pounds)

AUX3 = unlagged (ex-ante) rate of land modernization (thousand acres/year).

A gestation lag is introduced in grazing reserve development by Equation (BF29).

(BF29) Call DELAY (AUX3(t), AUX4(t), CROUT2(t), GRGDEL, DT, 3)

where:

DELAY = a FORDYN subroutine which introduces distributed delays with various properties (Llewellyn, 1965)

AUX3 = as defined in Equation (BF28)

AUX4 = actual rate at which land becomes operational as grazing reserve (thousand acres/year)

GRGDEL = gestation delay in grazing reserve development--years

CROUT2 = an array of intermediate rates necessary in simulation of the gestation delay (Llewellyn, 1965).

Equation (BF30) computes the total land in grazing reserves, LGM, as the time integral of AUX4.

(BF30) LGM(t+DT) = LGM(t) + DT*AUX4(t)

Equations (BF31) through (BF35) compute the rate at which animals enter the modern sector (and hence leave the traditional) as a function of the additional TDN made available by new grazing reserves and additions to acreage in animal feed crops. (It is assumed that feed crops are only supplied to animals in the grazing reserve sector.)

(BF31) RTDN(t) = AUX4(t)*B9 + RLC3(t)*B10

where:

RTDN = total rate of increase of TDN in the modern sector--thousand pounds/year-year (where TDN itself is a flow rate thousand pounds/year)

AUX4 = rate of increase in grazing land--thousand acres/year

B9 = pounds TDN/acre-year

RLC3 = rate of increase of animal feed crop land--thousand acres/year

B10 = pounds TDN/acre-year.

The rate at which animals are added to the modern grazing reserves is a function of the rate of increase of their traditional nutrition levels and the difference between the achieved nutrition level and the desired one. Equation (BF32) computes this.

(BF32) RAA(t) = RTDN(t)*B16 + B36*(TDNAM(t) - TDNAD(t))

where:

RAA = rate animals are added to the modern sector (thousand animals/year)

RTDN = rate of increase of TDN (thousand pounds/year-year)

B16 = the reciprocal of the TDN required per animal-year under "modern" nutritional standards (thousand animal-years/thousand pounds TDN)

B36 = a model parameter that determines the influence which the difference between the achieved nutrition level and the desired nutrition level in the modern sector has on the rate animals are added to the modern sector

TDNAM = pounds of TDN per animal in the modern sector

TDNAD = desired TDN level per animal in the modern sector.

The number of males and females which, summing to RAA, are added to the modern population is given by Equations (BF33) and (BF34). It is assumed in the model that the sex ratio of transferring animals is the same as that of the traditional population (this could also be a policy variable) or that:

(BF33) RFTT(t) = RAA(t)*(PFT(t)/(PFT(t) + PMT(t)))

(BF34) RMTT(t) = RAA(t) - RFTT(t)

where:

RFTT = rate females are transferred out of the traditional sector (thousand animals/year)

RMTT = rate males are transferred out of the traditional sector (thousand animals/year)

RAA = rate animals are added to the modern sector (thousand animals/year)

PFT, PMT = female and male populations in the traditional sector (thousand animals).

The rates animals leave the modern sector are the negatives of RFTT and RMTT (negative departures are arrivals):

(BF35) RFTM(t) = -RFTT(t)

(BF36) RMTM(t) = -RMTT(t)

Equations (BF33) through (BF36) compute the input variables required by subroutine DEMOG, and have utilized some of its outputs, PFT and PMT.

Fly Eradication Programs

Equations (BF37) and (BF38) introduce fly eradication programs into the model and compute the rate at which land is being freed of tsetse fly.

(BF37) AUX1(t) = EFE(t)*B1

where:

AUX1 = the unlagged rate at which land is being freed of fly (thousand acres/year)

EFE = expenditures on fly eradication (a policy variable)--(thousand pounds/year)

B1 = reciprocal of the eradication cost per acre (thousand acres/thousand pounds).

Equation (BF38) introduces a time lag to account for delays in program implementation.

(BF38) Call DELAY (AUX1(t), AUX2(t), CROUT1(t), FEGDEL, DT, 3)

where:

AUX1 = as above

AUX2 = actual rate at which fly-freed land becomes available for grazing

FEGDEL = fly eradication gestation delay--years.

The variable, AUX2, is integrated with respect to time to give LGFE--total land freed of tsetse fly.

Total crop land (which expands at the expense of grazing land in northern Nigeria) is computed by the land allocation component of the Northern model. Total crop land and the grazing land residual are computed as follows:

$FFLND(t) = TL_1(t) + TL_2(t) + TL_3(t)$

where:

FFLND = total crop land in the normally fly-free region of northern Nigeria

TL_1, TL_2, TL_3 = respectively, total crop land in the groundnut-food, cotton-food and groundnut-cotton-food zones.

LG(t) = LGO - FFLND(t) + LGFE(t)

where:

LGFE = land freed of tsetse fly as a result of eradication programs

LG = total fly-free grazing land

LGO = total fly-free grazing land at the beginning of a simulation run.

Equation (BF30) computed modern grazing land (in grazing reserves). Equation (BF39) computes land in traditional grazing.

(BF39) LGT(t) = LG(t) - LGM(t)

where:

LGT = grazing land (fly-free) in the traditional sector (thousand acres)

LG = total fly-free grazing area (thousand acres)

LGM = land in grazing reserves (thousand acres).

Range Conditions and TDN Availability

Many reports indicate that the condition of the traditional grazing land in northern Nigeria is deteriorating because of overgrazing. This effect, if present in fact, is introduced into the model by Equations (BF40) and (BF41).

(BF40) GRT(t) = LGT(t)/(PFT(t) + PMT(t))

where:

GRT = grazing rate in the traditional sector (acres/animal)

LGT = total fly-free grazing area (traditional)

(PFT + PMT) = total traditional animal population.

(BF41) RCON(t+DT) = RCON(t) + DT*B4*(GRT(t) - GRE)

where:

RCON = range condition (a dimensionless number)

GRE = equilibrium grazing rate (which results in constant range condition)--acres/animal

GRT = actual grazing rate as computed in Equation (BF40)

B4 = a parameter that determines the extent of influence of grazing rate upon range condition.

Range condition is prevented from diminishing below an unrealistic limit by establishing a lower bound for RCON. The above equations stipulate that range condition increases or decreases over time if GRT is, respectively, greater or less than GRE.

Given range condition, it is now possible to compute the total TDN available from the fly-free grazing land.

(BF42) TDNGT(t) = RCON(t)*B3*LGT(t)

where:

TDNGT = total (traditional) TDN from grass in fly-free northern Nigeria (thousand pounds/year)

LGT = total fly-free grazing area available to traditional herds (thousand acres)

RCON = range condition

B3 = TDN yield per acre--thousand pounds/thousand acres.

The definitions of RCON and B3 are interdependent. If RCON is assigned the value 1 at the start of a simulation run (corresponding to a particular year), then B3 is the yield per acre in that year. If RCON is assigned a value 1 corresponding to maximum climax vegetation, then B3 is the maximum climax yield per acre.

The TDN available to the traditional sector from crop residues, TDNRES, is computed by the crop sectors of the Northern model. Equation (BF43) computes the total TDN in the traditional sector.

(BF43) TDNT(t) = TDNGT(t) + TDNRES(t) + B7*B8*LGF(t)

where:

TDNT = total TDN available to the traditional sector (thousand pounds/year)

TDNGT = TDN from fly-free grassland (thousand pounds/year)

TDNRES = TDN from fly-free crop residues (groundnuts, cotton and food)--thousand pounds/year

LGF = grassland in fly-infested region--thousand acres

B8 = proportion of fly-infested grassland that is available to animals during the dry season when the fly recedes

B7 = thousand pounds of TDN/acre in the fly-infested area.

The last term in Equation (BF43) represents TDN which animals acquire in fly-infested areas during the dry season from LGF--fly-infested grazing land. More precisely, LGF should change with time due to growth of crop land, etc. (as does LG), but this second order effect was not included in the model.

Equation (BF44) computes the per-animal TDN in the traditional sector--an important input variable for subroutine DEMOG.

(BF44) TDNAT(t) = TDNT(t)/(PFT(t) + PMT(t))

where:

TDNAT = TDN per animal in the traditional sector--thousand pounds/thousand animal-years

TDNT = total TDN

PFT, PMT = female and male population sizes in the traditional sector.

Equations (BF45) through (BF48) compute the corresponding per-animal TDN for the modern sector.

(BF45) TDNGM(t) = LGM(t)*B9

(BF46) TDNFC(t) = LC3(t)*B10

(BF47) TDNM(t) = TDNGM(t) + TDNFC(t)

(BF48) TDNAM(t) = TDNM(t)/(PFM(t) + PMM(t))

where:

TDNGM = TDN from grass in the modern sector--thousand pounds/thousand acre-years

TDNFC = TDN from (animal) feed crops--thousand pounds/thousand acre-years

LGM = land in modern grazing reserves--thousand acres

LC3 = land in animal feed crops--thousand acres

B9, B10 = thousand pounds TDN/thousand acre-years

TDNM = total TDN in the modern sector

TDNAM = per-animal TDN

PFM, PMM = sizes of female and male populations in the modern (grazing reserve) sector.

Criteria Variables

The remaining model statements and equations compute a number of variables useful in assessing various modernization policies and provide also for the printing of model output data.

Equations (BF49), (BF50) and (BF51) compute demand, supply and imports of beef.

(BF49) DEM(t) = DI*EXP(AL1*T)

where:

DEM = total Nigerian demand for beef--thousand animals/year

DI = initial demand (at the beginning of a given simulation run)

AL1 = a model parameter which determines rate of growth of demand

T = time

EXP = exponential function.

This equation assumes that demand grows exponentially due to population and income effects.

(BF50) SUP(t) = SFT(t) + SMT(t) + B11*(SFM(t) + SMM(t)) + B12*(DFT(t) + DMT(t))

+ B13*(DRM(t) + DMM(t))

where:

SUP = supply--thousand animals/year (from northern Nigerian herds)

SFT, SMT, SFM, SMM = sales of females and males in the traditional and modern sectors--thousand animals/year

DFT, DMT, DFM, DMM = natural deaths--thousand animals/year

B12, B13 = proportion of natural deaths which are marketed--dimensionless

B11 = a factor, greater than 1, to account for heavier animals produced in the modern sector.

Imports necessary to satisfy demand are computed as the residual between demand and supply.

(BF51) CIMP(t) = DEM(t) - SUP(t)

where:

CIMP = computed imports--thousand animals/year

DEM, SUP = demand and supply.

Equations (BF52) and (BF53) compute the income derived from cattle in the traditional and modern sectors, respectively.

(BF52) YAT(t) = SUPT(t)*PA(t) + PAD*(DMT(t) + DFT(t))

(BF53) YAM(t) = SUPM(t)*PA(t) + PAD*(DMM(t) + DFM(t))

where:

YAT = income derived from cattle in the traditional sector--thousand pounds/year

SUPT = number of cattle sold in traditional sector--thousands/year

PA = price of cattle in £/animal

PAD = value received for dead animals--mostly hide sales--thousand pounds/year

DMT = number of male deaths--thousand/year

DFT = number of females that died--thousand/year.

The total income derived from the beef industry is the addition of the traditional herd income and the modern herd income. Equation (BF54) reflects this.

(BF54) YA(t) = YAT(t) + YAM(t)

where:

YA = income derived from the beef industry.

Equations (BF20) and (BF21) of subroutine DEMOG compute the quantity and value of milk produced by the traditional and modern herds.

(BF20) QM = PF(t)*PFCA*YMA*TABLIE(VAL5, 1360., 1360., 1, TDNA)

(BF21) YM(t) = QM(t)*PRM(t)

where:

QM = quantity of milk produced--thousands of pounds (avoir.) per year (modern and traditional)

PF = female population in thousands

PFCA = proportion of females lactating

YMA = average annual output per animal in pounds per animal

TABLIE(VAL5 . . .) = a subprogram which introduces a milk production factor determined by level of nutrition--TDNA (Llewellyn, 1965)

YM = income from milk in thousands of pounds/year

PRM = price of milk in £/pound.

Incomes from traditional and modern milk are summed to give total milk income.

Equation (BF55) computes the operating costs of grazing reserve programs.

(BF55) COGR(t) = LGM(t)*B14

<u>where</u>:

COGR = operating costs of grazing reserves--thousand pounds/year

LGM = total land in grazing reserves--thousand acres

B14 = costs of operating grazing reserves--thousand pounds/thousand acres.

The depreciation of grazing reserve capital, GRDEP, is computed by (BF56).

(BF56) Call DELAY(EXGR(t), GRDEP(t), CROUT3(t), GRDEPD, DT, 3)

This specifies that capital has a mean useful life of GRDEPD years. Given the costs and incomes computed above, it is now possible to compute an overall discounted cash flow criterion function which may be one evaluative measure useful in evaluating alternative modernization policies. Equation (BF57) performs this function.

(BF57) CF(t+DT) = CF(t) + DT*((YA(t) + YM(t) + EXGR(t) - COGR(t) - EFE(t)

- GRDEP(t))*EXP(-AL3*T))

<u>where</u>:

CF = cash flow--thousand pounds

YA = income derived from beef--thousand pounds/year

YM = income derived from milk--thousand pounds/year

EFE = expenditure on fly eradication--thousand pounds/year

EXGR = capital expenditures on grazing reserves--thousand pounds/year

COGR = operating costs of grazing reserves

GRDEP = depreciation of grazing reserve capital--thousand pounds/year

AL3 = the discount rate

T = time

EXP = exponential function.

Note that this cash flow function, by including farm income generated from meat and animals, implicitly includes the effects of range deterioration and associated reduction in available TDN. It does not, however, include soil deterioration or related capital losses which may be caused by overgrazing. While the incomes are farm incomes, the expenses are (assumed to be) government expenses. Consequently, other criterion functions may be more appropriate for particular decisions.

The beef component also includes a number of other performance measures which may be useful in evaluating alternative modernization policies. These are as follows:

(BF58) FARMI(t) = YA(t) + YM(t)

where:

FARMI = total income (thousand pounds per year) generated from meat and milk in fly-free northern Nigeria.

(BF59) FARMIA(t+DT) = FARMIA(t) + DT*FARMI(t)

where:

FARMIA = accumulated farm income--thousand pounds.

(BF60) FOREXB(t) = B28*CIMP(t)*PA(t)

where:

FOREXB = foreign exchange earnings from beef--thousand pounds/year

CIMP = cattle imports--thousand animals/year

PA = price per animal

B28 = price adjustment factor (All model prices are producer prices.)

(BF61) FOREXBA(t+DT) = FOREXBA(t) + DT*FOREX(t)

where:

FOREXBA = accumulated foreign exchange earnings from beef--thousand pounds.

(BF62) ANPROT(t) = B29*SUP(t) + B30*QM(t)

where:

ANPROT = animal protein--thousand pounds/year

SUP = supply of animals--thousand animals/year

QM = total milk output--thousand pounds/year

B29, B30 = pounds of protein/pound.

(BF63) GRCAP(t+DT) = GRCAP(t) + DT*(EXGR(t) - GRDEP(t))

where:

GRCAP = value of capital investment in grazing reserves--thousand pounds

EXGR = capital investment in grazing reserves--thousand pounds/year

GRDEP = capital depreciation of grazing reserves--thousand pounds/year.

(BF64) VALCAP(t) = (PFT(t) + PMT(t) + B11*(PFM(t) + PMM(t)))*PAA(t) + GRCAP(t)

where:

VALCAP = total value of animal population and related industry capital--thousand pounds

PAA = average value per animal--£/animal

PFT, PMT, PFM, PMM = animal populations--thousand animals

B11 = a factor to increment the value of animals in the modern sector.

This completes a mathematical description of the beef-milk component of the Northern model.

Data Included in Monte Carlo Runs of the Northern Model

The following tables include the values used in Monte Carlo runs of the Northern model, described in the body of Chapter IV (Tables 4.2 and 4.4). For the most part these data were obtained from experts, Nigerian and American, with substantial experience in Nigerian agricultural development.

TABLE 4.A.3
Summary of Data Values Used in the Monte Carlo Runs of the Northern Model.

Description	Units	Lower Limit	Most Likely Value	Upper Limit	Designation	Component
Percent of land in least profitable cash alternative that transfers to most profitable alternative /year/% difference in returns to labor	%/yr. / %	.15	.75	1.25	CL1, CL4	LANDN
Proportion of farm population (or farm labor force) in Region 1 that is active in producing cash crops (two values--1970 and 1960--excludes nomadic Fulani.)	--	1970 .5	.75	.80	EAP_1	LANDN
		1960 .5	.75	.80	$EAP_1(0)$	
Same as above for Region II.		1970 .35	.55	.65	EAP_2	LANDN
		1960 .30	.50	60	$EAP_2(0)$	
Same as above for Region III.		1970 .45	.75	.80	EAP_3	LANDN
		1960 .45	.75	.80	$EAP_3(0)$	
Same as above for Region IV. (Food for export from local area.)		1970 .40	.70	.75	EAP_4	LANDN
		1960 .35	.60	.65	$EAP_4(0)$	
Annual price elasticity of cash crop supply in Region I. Prices greater and less than "normal" (upward price change = downward price change).	%/%	Prices > normal .7	1.5	2.0	$BPF_{1,1}$	LANDN
		Prices < normal 0	.5	1.0	$BPF_{2,1}$	
Same as above for Region II.	%/%	Prices > normal .75	1.0	1.5	$BPF_{1,2}$	LANDN
		Prices < normal 0	.5	.8	$BPF_{2,2}$	
Same as above for Region III.	%/%	Prices > normal .1	.8	1.2	$BPF_{1,3}$	LANDN
		Prices < normal 0	.5	1.0	$BPF_{2,3}$	
Same as above for Region IV (food exported from local area).	%/%	Prices > normal 1.0	1.5	2.0	$BPF_{1,4}$	LANDN
		Prices < normal .3	.5	.8	$BPF_{2,4}$	
Labor requirements for cultivation of groundnuts.	man-months/acre	Traditional .6	1.0	1.5	$C4_1$*12	AMP
		Modern				
Same as above for cotton.	man-months/acre	Traditional .4	.96	2.5	$C4_2$*12	AMP
		Modern				
Same as above for food grown in competition with groundnuts and cotton.	man-months/acre	Traditional 1.5	2.2	2.6	$C4_3$*12	AMP
		Modern				
Same as above for food grown in Region IV (food exported from local area).	man-months/acre	Traditional 1.5	2.2	2.6	$C4_4$*12	AMP
		Modern				

Table 4.A.3 continued

Description	Units	Lower Limit	Most Likely Value	Upper Limit	Designation	Component
Labor requirements for harvesting groundnuts (includes shelling).	man-months/ lb.	Traditional .0015 Modern	.002	.003	$C5_1$*12	AMP
Same as above for seed cotton.	man-months/ lb.	Traditional .0025 Modern	.0036	.006	$C5_2$*12	AMP
Same as above for food grown in competition with groundnuts and cotton (staple foods like grains, millet, etc.).	man-months/ lb.	Traditional .00045 Modern	.00062	.00079	$C5_3$*12	AMP
Same as above for food in Region IV (staple foods like yams, cassava, etc.).	man-months/ lb.	Traditional .00045 Modern	.00062	.00079	$C5_4$*12	AMP
Net traditional groundnut yield (net of harvesting losses).	lbs./ acre	450	595	800	PYT_1	AMP,MOD
Traditional seed cotton yield.	lbs./acre	140	221	300	PYT_2	AMP,MOD
Traditional food yield in Regions I, II and III (staple foods like grains, millet, etc.).	lbs./acre	360	600	900	PYT_3	AMP,MOD
Traditional food yield in Region IV (staple foods like yams, cassava, etc.).	lbs./acre	3,500	4,250	7,000	PYT_4	AMP,MOD
Net "modern" groundnut yield. (Modern here relates to recommended practices for near term extension production campaigns.)	lbs./acre	800	1,000	1,500	PYM_1	MOD
Same as above for seed cotton.	lbs./acre	300	400	750	PYM_2	MOD
Same as above for food in Regions I, II, III. (Food is from grain crops.)	lbs./acre	900	1,500	2,100	PYM_3	MOD
Same as above for food in Region IV (mainly roots).	lbs./acre	5,600	9,000	11,300	PYM_4	MOD
Marketing loss coefficient proportion of output lost between farm and consumer. Groundnuts: farm to export.	per year	.05	.1	.20	$1\text{-}C9_1$	AMP
Same as above for cotton: harvest to gin.	per year	.05	.10	.20	$1\text{-}C9_2$	AMP
Same as above for food in Regions I, II, III: farm to consumption.	per year	.20	.30	.40	$1\text{-}C9_3$	AMP
Same as above for food in Region IV: farm to consumption.	per year	.20	.25	.35	$1\text{-}C9_4$	AMP
Annual hired wage rate in agriculture--1960.	£ / man-year	43.5	60	75	WR	AMP
Maximum feasible adoption rate per extension worker promoting a modernization campaign for groundnuts.	acres/year / man-year	1,000	2,000	2,500	$E31_1$	MOD

Table 4.A.3 continued

Description	Units	Lower Limit	Most Likely Value	Upper Limit	Designation	Component
Same as above for cotton.	acres/year / man-year	1,000	2,000	2,500	$E31_2$	MOD
Same as above for food in Regions I, II, III.	acres/year / man-year	1,000	2,000	2,500	$E31_3$	MOD
Same as above for food in Region IV.	acres/year / man-year	1,000	2,000	2,500	$E31_4$	MOD
Pounds of seeds and/or cuttings per acre of modernized land.	lb /acre groundnuts	112	130	150	$E13_1$	
	cotton	15	25	28	$E13_2$	
	Food 1-3	15	16.5	18	$E13_3$	MOD
	Food -4	700	850	1,400	$E13_4$	
Pounds of commercial fertilizer required per acre for transition land (groundnuts).	lb./acre	10	30	75	$E141_1$	MOD
Same as above for land in diffusion process (groundnuts).	lb./acre	10	25	50	$E142_1$	MOD
Pounds of fertilizer required per acre for modernized land (groundnuts).	lb./acre	50	100	120	$E143_1$	MOD
Same as above for traditional acres (groundnuts).	lb./acre	0	0	3	$E144_1$	MOD
Same as above transition (cotton).	lb./acre	20	60	100	$E141_2$	MOD
Same as above diffusion (cotton).	lb./acre	20	50	75	$E142_2$	MOD
Same as above modernized (cotton).	lb./acre	100	150	200	$E143_2$	MOD
Same as above traditional (cotton).	lb./acre	0	0	3	$E144_2$	MOD
Same as above for food Regions I - III (transition).	lb./acre	20	30	45	$E141_3$	MOD
Same as above for food Regions I - III (diffusion).	lb./acre	15	25	40	$E142_3$	MOD
Same as above for food Regions I - III (modernized).	lb./acre	75	125	150	$E143_3$	MOD
Same as above for food Region IV (transition).	lb./acre	100	165	200	$E141_4$	MOD
Same as above for food Region IV (diffusion).	lb./acre	75	100	125	$E142_4$	MOD

Table 4.A.3 continued

Description	Units	Lower limit	Most Likely Value	Upper Limit	Designation	Component
Same as above for food Region IV (modernized).	lb./acre	150	200	250	$E143_4$	MOD
Minimum amount by which profit from modern production would need to exceed traditional production to get traditional farmer to adopt.	% Groundnuts % Cotton % Cash Food	5 5 2	10 10 10	25 25 25	$E9_1$ $E9_2$ $E9_3$,$E9_4$	MOD
Credit required per year per acre to sustain modern production assuming no subsidy program.	£/acre/year Groundnuts Cotton	1 2	2 3	3 4	$E151_1$ $E151_2$	MOD
	Food 1-3 Food -4	1 2	2 3	3 4	$E151_3$ $E151_4$	
Maximum proportion of traditional groundnut land per year that will enter modern production as a result of demonstration effects (no extension promotion and high relative profitability).	per year	.05	.10	.2	E10/4	MOD
Same as above for cotton.	per year	.05	.10	.2	E10/4	MOD
Same as above for cash food.	per year Region III Region IV	.05 .05	.10 .10	.2 .2	E10/4	MOD
Extension worker equivalents per acre of land in a production campaign for groundnuts.	men/acre Start of Campaign End of Campaign	.0066 .0017	.01 .0025	.013 .003	$E51_1 + E52_1$ $E51_1$	MOD
Same as above for cotton.	men/acre	.0066 .0017	.01 .0025	.013 .0030	$E51_2 + E52_2$ $E51_2$	MOD
Same as above for food in Regions I, II, III.	men/acre	.0066 .0017	.01 .0025	.013 .0030	$E51_3 + E52_3$ $E51_3$	MOD
Same as above for food in Region IV.	men/acre	.0066 .0017	.01 .0025	.013 .003	$E51_4 + E52_4$ $E51_4$	MOD
Average time required for farmers to start producing at modern levels (measured from time of entrance into a modernization program) with promotion (groundnuts).	years	2	3.5	5	$DEL2_1$	MOD
Same as above for cotton.	years	2	3.5	5	$DEL2_2$	MOD

Table 4.A.3 continued

Description	Units	Lower Limit	Most Likely Value	Upper Limit	Designation	Component
Same as above for food in Regions I, II, III.	years	3.5	4	5	$DFL2_3$	MOD
Same as above for food in Region IV.	years	3	4	5.5	$DFL2_4$	MOD
Average time required for farmers to start producing at modern levels after a decision to adopt modern practices via diffusion - (groundnuts, no promotion).	years	1.5	3	5	$DEL3_1$	MOD
Same as above for cotton.	years	1.5	3	5	$DEL3_2$	MOD
Same as above for food in Regions I, II, III.	years	1.5	3	5	$DEL3_3$	MOD
Same as above for food in Region IV.	years	2	4	5	$DEL3_4$	MOD
Forecasted % change in world groundnut prices beyond 1971.	%/yr.	-.04	-.02	0	CW2	MOD
Same as above for cotton price.	%/yr.	-.04	0	.02	CW1	MOD
Percentage of persons employed in agriculture that migrate out of ag sector to nonag sector. North	%/yr. males	.5	.75	4.0	$RUM_{1,1}$	POP
	females	.5	.5	2.0	$RUM_{2,1}$	POP
Same as above for South.	%/yr. males	1.0	2.0	5.0	$RUM_{1,2}$	POP
	females	.5	1.0	3.0	$RUM_{2,2}$	POP
Price elasticity of cattle supply.	%/%	.9	1.0	1.1	ELASI	Cattle
Milk price.	£/lb.	.0075	.01	.0125	PRMT	Cattle
Milk output per lactating female.	£/animal year	710	950	1,190	YMAT	Cattle
Initial fly-free grazing land (at start of simulation) in northern Nigeria.	Thousand acres	42,300	47,000	51,700	LGO	Cattle
Fly-infested grass land area.	Thousand acres	66,600	74,000	81,400	LGF	Cattle
Acres of fly-infested land cleared (and kept clear) of tsetse fly per £.	Acres/£	.25	.33	.41	B1	Cattle
Acres of grazing reserve developed per £ of expenditure.	Acres/£	4.3	5.75	7.2	B2	Cattle
TDN yield of fly-free grazing land.	Lbs. TDN/acre	130	130	248	B3	Cattle

Table 4.A.3 continued

Description	Units	Lower Limit	Most Likely Value	Upper Limit	Designation	Component
Parameter determining rate of grass land deterioration in response to over grazing.	animals/acre	0	0	.009	B4	Cattle
TDN yield of fly-infested grass land.	Lbs. TDN/acre	200	200	500	B7	Cattle
Proportion of fly-infested land grazed during the dry season.	Dimensionless	.1	.25	.4	B8	Cattle
Proportion of traditional males sold annually.	per year	.188	.208	.228	B35	Cattle
Random factor affecting traditional birth-rates.	Dimensionless	.71	.94	1.4	B41	Cattle
Random factor affecting traditional death rates.	Dimensionless	.77	.97	1.5	B42	Cattle

CHAPTER V

The Southern Region Model: Annual and Perennial Crops

THE SOUTHERN MODEL is designed to simulate the economic behavior of the agricultural sector of a region where annuals and perennials compete for scarce resources. The objective is to provide a tool with which the decision maker can conduct policy experiments as part of the development planning process. Following the building block approach, the model is composed of a number of units representing specific classes of activities or functions within the southern agricultural economy. Figure 5.1 indicates the major flows and activities in this model.

This chapter begins with a brief description of the southern region and its ecological zones of competing commodities. Next, the five components of the model are described in detail, with references to the equations in Appendix V.B. A discussion of data requirements and model testing procedures follows, and the chapter closes with the presentation of the results of sample policy runs.

"Southern" Nigeria

The "Southern" Nigeria described in this model encompasses the six southern states of the Federal Republic of Nigeria. The basis for this "political" definition rests on ecological, cultural and (thus) economic considerations.

Ecologically, the six southern states range from rain forest to intermediate savanna where annual crops typically compete with perennials (cocoa, rubber and oil palm) for scarce resources. In those areas where perennials are not viable alternatives--particularly Oyo Division and the northern divisions of the Southeastern State--annuals (food) may compete with other annuals (tobacco or cotton), as in the North, but the people of these areas are more economically and culturally tied to the South. Thus, the economic behavior of these people--which, as we shall see, is the foundation upon which the model is built--is probably more like that of the rest of the southern population than of the people in the North.

A major economic rationale for this particular regional delineation concerns the specific resources considered scarce in each region. The North is a land-rich, labor-poor economy. Land allocations are thus based on economic returns to labor. In the South, however, land and capital appear to be the major constraints to the expansion or modernization of agricultural production, while labor, considering seasonal migration from the North, is not a limiting factor. Thus, land in the South is allocated to various enterprises according to the relative returns to land, and the allocations are constrained by the capital available.

Ecological Zones

Land use decisions in the South are based on the four ecological zones (or crop sectors) of competing cropping activities (determined roughly by climatic and soil conditions (FAO, 1966)) defined in the model. (These zones or areas, which are designated as "sectors" in the Southern model, correspond to the "regions" in the Northern model.) Figure 5.2 is a Venn diagram of these zones.

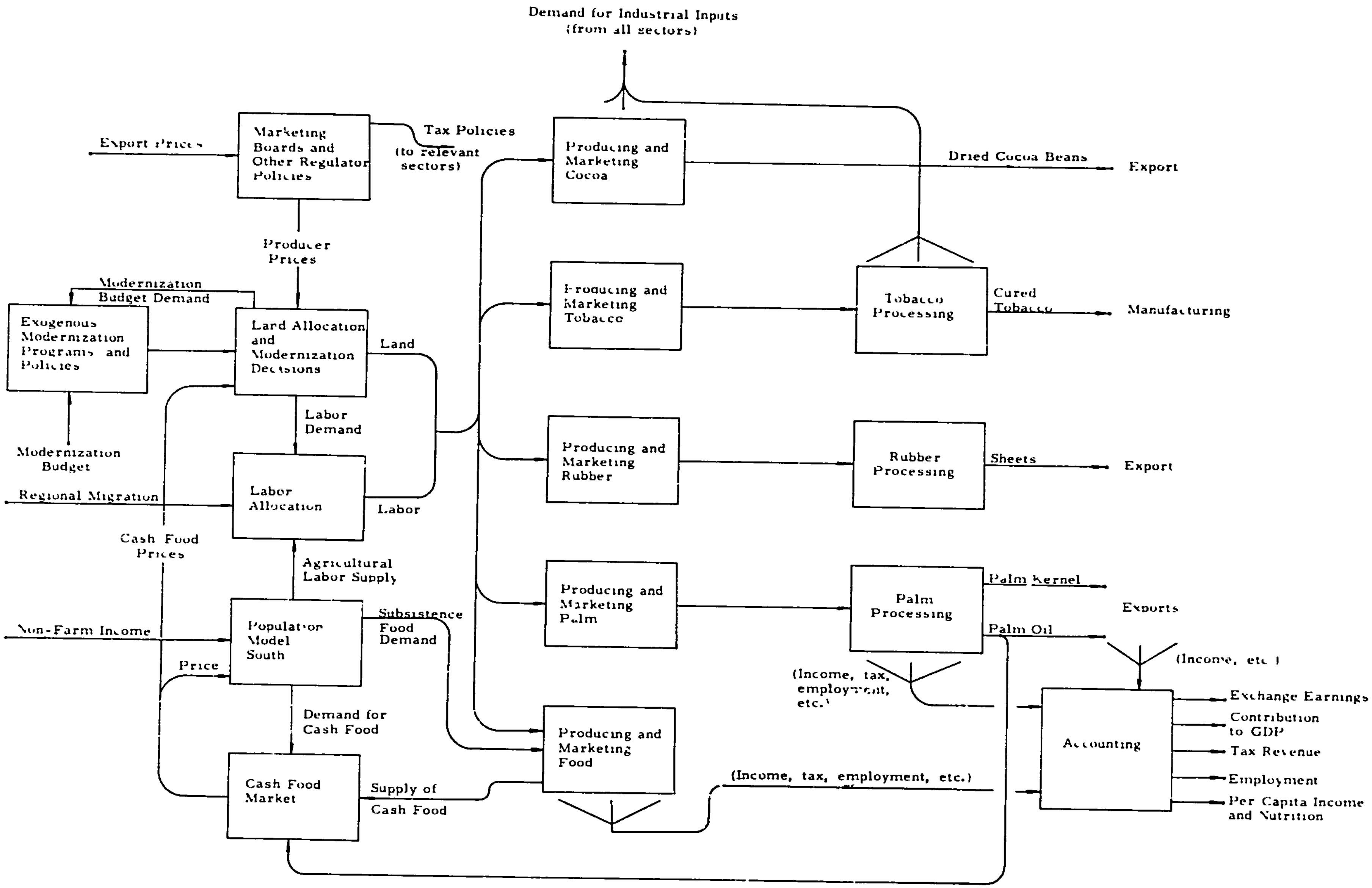


Figure 5.1. Major sectors and interactions of the southern Nigerian agricultural model.

Sector 1 is the area where cocoa competes with food crops for land and capital. This sector covers all of the Western State (except Egbado, Oyo and Okitipupa Divisions) and Afenmai Division of the Mid-West. Although palm is a possible competitor to cocoa, the simplifying assumption is made that it is not really an economically viable alternative. In the major cocoa-growing areas of the Western State, the profitability of cocoa relative to palm is such that cocoa production by far dominates palm production. Aside from the mere collection of wild palm fruits, farmers do not consider investment in the cultivation or modernization of palm a significant alternative. Thus, in Figure 5.2, the Cocoa Sector circle does not overlap the Palm Sector circle. The wild palm harvested in the Cocoa Sector is included in the model as produce of the bush areas. The model can be revised if further evidence calls this assumption into serious question.

In Sector 2, oil palm is the primary competitor with food for inputs. This includes all of the three Eastern states with the exception of the following divisions: Brass, Degema, Nsukka, Udi, Abakaliki, Ogoja, Obudu and Ikom.

Okitipupa Division of the West and the Mid-West State minus Afenmai and Western Ijaw Divisions comprise Sector 3, where oil palm, rubber and food all compete for resources.

The remainder--including Lagos State, those parts of the West not in Sector 1, those parts of the East not in Sector 2, and Western Ijaw Division of the Mid-West--comprises Sector 4, the areas where only food can be economically farmed. In portions of this sector, other cash annuals, e.g., cotton or tobacco, may compete with food.

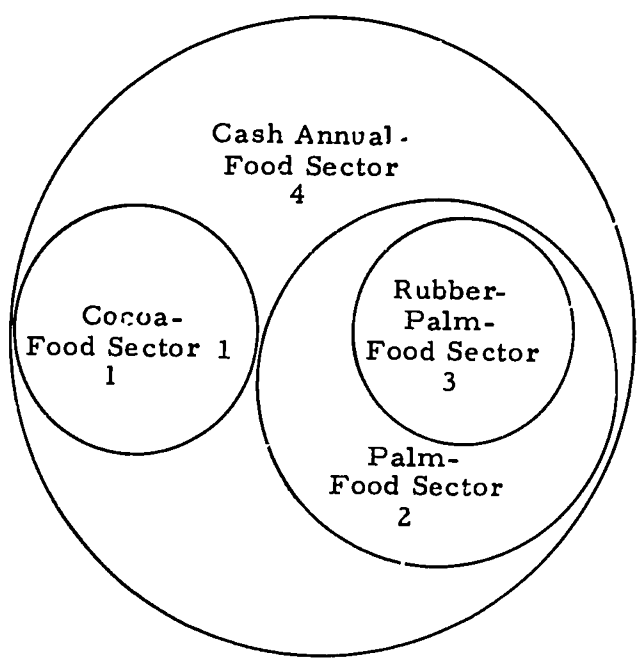


Figure 5.2. Venn diagram of the ecological zones of southern Nigeria.

These ecological zones are not entirely internally homogeneous. For example, not all the food land in the Cocoa Sector is suitable for cocoa, and vice versa. Thus, although the crop sectors are defined for ecologically competitive crops, compromises were made to delineate the ecological zones as contiguous areas. (The only exception to this is the Food Sector.) The primary reasons for this are twofold. First, any given farmer may hold some land suitable only for cocoa, some only for food and some where either is feasible. Since the infrastructure and the behavioral characteristics of farmers, e.g., risk aversion and confidence in government experts, which control the land use and modernization decisions, are probably somewhat determined by contiguous areas of social contact, a case can be made for compromising strictly "ecological" zones. Second, we will be interested in performing an agricultural sector budget accounting for each ecological zone. This budget includes not only agricultural income and investment but also consumption expenditures of the population. To the extent that consumption depends on common behavioral considerations, contiguous crop sectors again appear suitable.

Logical Components

The computer simulation model of the agricultural economy of southern Nigeria is composed of five basic units or logical components (See Figure 5.3.) Two of these components are the basic building blocks of the simulation model: (1) land allocation and modernization decisions, and (2) agricultural marketing, production and processing. A third generates world, market, processor and producer prices. The remaining two units are the entry and exit points of the system where: (4) policies are set and (5) budget accounting is performed and performance variables are generated. Each of these components will now be described in some detail.

Land Allocation and Modernization Decisions--

Annuals/Perennials (LAMDAP)

Component LAMDAP of the simulation model allocates land to the production of the various commodities grown in each of the four ecological zones (crop sector) described earlier (Figure 5.2): the Cocoa-Food Sector, the Palm-Food Sector, the Rubber-Palm-Food Sector and the Food-Cash Annual Sector. In making these allocations, LAMDAP simulates farmers' choices among the alternative uses for their land based on economic and cultural factors. Modernization of current land uses is an alternative as is transferring land into the production of alternative commodities.

Land Uses

In general, the land uses in the ecological zones include traditional and modern perennials, annuals and bush. Specifically, Sector 1 has traditional and modern cocoa, food[1/] and bush, while Sector 2 has traditional and modern palm, food and bush. Sector 3, with two perennials competing, includes traditional and modern rubber, traditional and modern palm, food and bush. In Sector 4, the alternative to food and bush is tobacco, although the general mechanism could incorporate consideration of a cash annual other than tobacco, e.g., cotton or kenaf.

1/ *See Appendix V.A for the definition of food used in this model.*

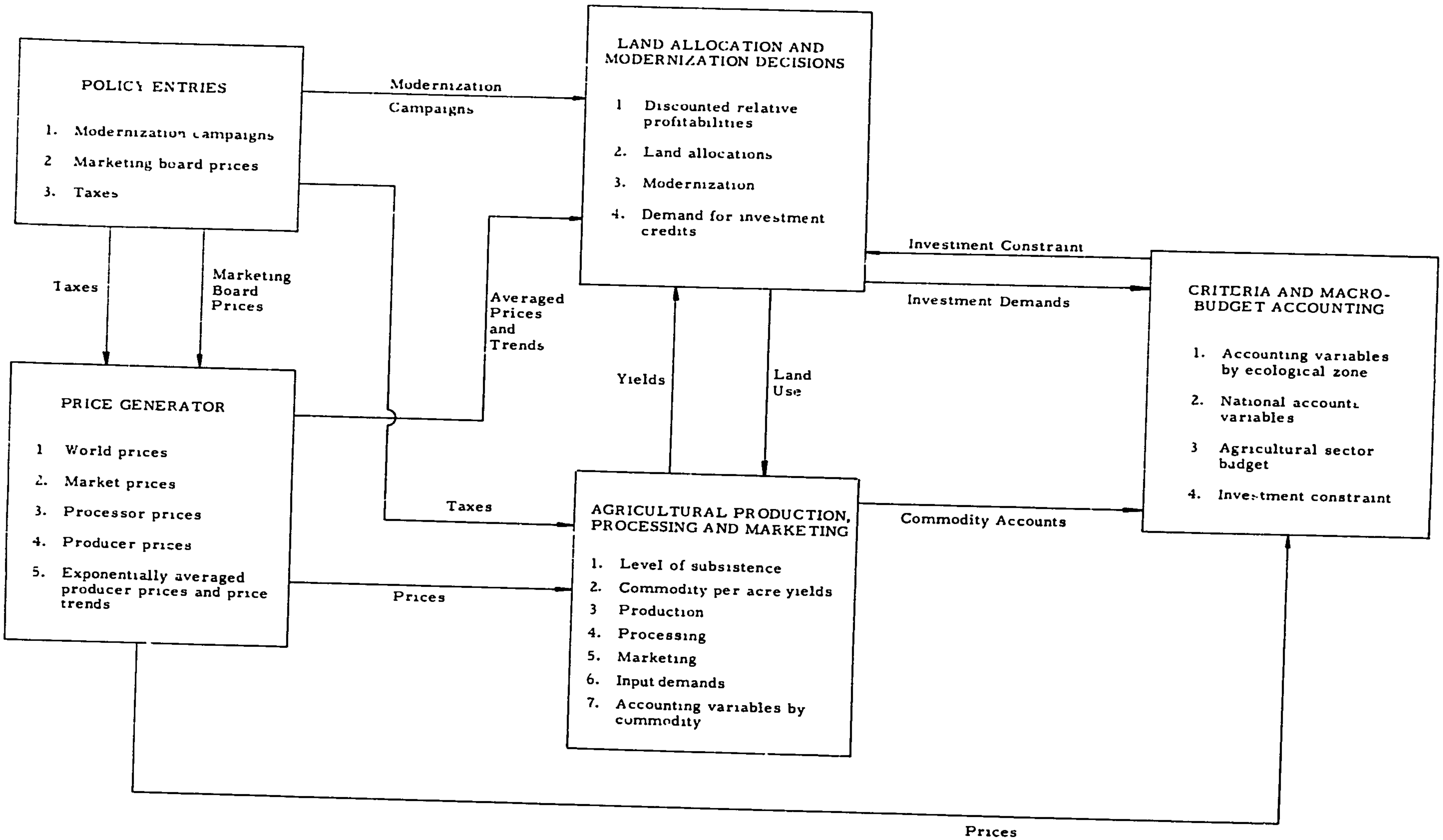


Figure 5.3. Building blocks of the southern model.

Perennials

A perennial crop consists of a population of trees of various ages, i.e., trees planted at different times. Since certain characteristics of these trees depend on their age, e.g., yields and labor requirements, the age distribution of trees is very important in determining the output of the crop and thereby the foreign exchange, tax revenue, income and other benefits accruing to the public and private participants. Thus, it is useful to model the tree crops along the lines of a demographic model; that is, the perennial population ages through time, with births (new plantings) and deaths generating a dynamic and, as we have seen, crucial age distribution.

The demographic model of the tree crops is divided into five age cohorts of varying lengths (Figure 5.4). The respective cohort lengths reflect the five production stages of a perennial crop which the model identifies: the gestation stage, a stage of rising yields, a stage of maximum yields, a declining yield stage and a stage of old trees where yields remain at some nominal level. The aging of trees through the first four cohorts is modeled by distributed lags (discussed below). When trees finally enter the old age cohort, their aging rate is no longer modeled, and trees remain there indefinitely producing nominal yields to reflect their being phased out of production. The model may easily be modified to incorporate a death rate for trees in this last stage. However, rather than actual "death," this is more of an economic decision of the farmers to permanently abandon old trees (thus allowing eventual reversion to bush), i.e., an economic death rather than a physical death. Such abandonment is thus determined in the model as a land use decision in the same manner as are planting rates (births) and transitions out of the population to other commodities, modern or traditional.

The distributed lag model (Llewellyn, 1965) allows us to simulate, in effect, a probability density for the time it takes trees to pass through each stage (Manetsch, 1966); i.e., not all trees entering a particular production stage at the same time will leave it at the same time. For example, suppose the stage of rising yields is a six-year cohort (as it is for traditional palm). Some trees entering this stage after gestation may actually reach maximum yields in less than six years, while others may require considerably more time. On the average, however, traditional palm trees take about six years, once they begin to bear, to reach maximum yields.

Modern vs. Traditional.--There are eight perennial population streams in the model: (1) traditional cocoa; (2) modern cocoa; (3) traditional palm (Palm

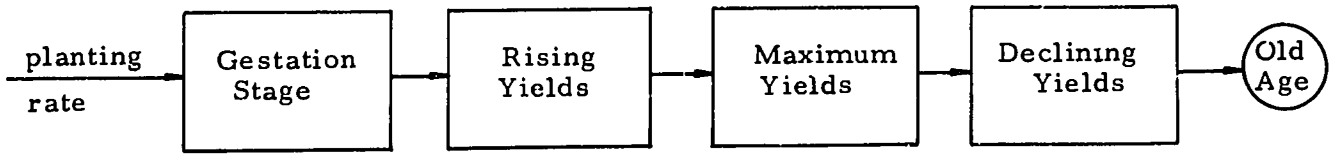


Figure 5.4. Perennial production cohorts.

Sector); (4) modern palm (Palm Sector); (5) traditional rubber; (6) modern rubber; (7) traditional palm (Rubber-Palm Sector), and (8) modern palm (Rubber-Palm Sector). All streams are modeled (Equation (L1))[2/] as shown in Figure 5.4, but the lengths of the production stages differ from one perennial to another. Such biological differences, e.g., cohort lengths, yields, are the primary reason for modeling modern and traditional perennials separately. However, the difference between the modern and traditional population streams of a perennial commodity is not only biological, i.e., modern high-yielding and/or disease resistant hybrids versus traditional low-yielding, diseased varieties, but also cultural. The term "modern" also encompasses improved managerial practices such as spraying, weeding, fertilizing, spacing and pruning. Improved harvesting techniques, particularly rubber tapping, are also subsumed under "modern."

Substreams.--Each perennial population stream is further divided (Equation (L2)) into two subpopulations, or substreams. In the case of the traditional perennials, i.e., traditional biological varieties, the two substreams (improved and traditional) are distinguished by the cultivation practices used, i.e., modern inputs and methods versus traditional. The modern cultivation practiced in the improved traditional substreams is the same as in the modern streams, but the latter includes new (higher-yielding, disease-resistant) biological varieties. The two substreams of the modern perennial population streams--replanted and new planted--represent new varieties planted on former traditional perennial land and on former bush or food land, respectively (or, in the case of Sector 3, on land formerly in the traditional stream of the other perennial, i.e., rubber or palm).

The primary reason for defining two distinct substreams is that yields and input demands may differ between them. This is certainly the case for the traditional and improved substreams of the traditional perennials. Such differences between newly planted and replanted modern perennial commodities are less obvious, however, and a case could be made for simplifying the model by merging these two substreams. But there is a third, important advantage to be gained by maintaining the distinction. Improvement, replanting and new planting are all modern alternatives that may be stimulated by overt, exogenous production campaign policies. As such, it is essential that the economic returns and costs of each of them separately be available in order to evaluate the alternative promotion policies. Thus, the model keeps track of replanted and newly planted modern perennials separately, as it does with traditional perennial varieties cultivated under improved and traditional methods.

Annuals

Food land (Equation (L3)) is land on which either subsistence or cash food is actually in production. There are also two subcategories (or "substreams," although there is no aging process as with the perennials) of food land: modern and traditional. The same rationale discussed above for the perennial substreams holds for the food substreams, the modernization of food production also being a potential production campaign policy.

Tobacco in Sector 4, or any other cash annual, is treated in the same manner as food, but there are no substreams. It is assumed there is no cash annual other than food traditional to the area. Therefore, any production of tobacco, cotton,

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See Appendix V.B, page 180 for an exposition of the equations of component LAMDAP.

or whatever, will have to have been exogenously promoted; thus we can assume it will be only modern.

Bush is all unused arable land, including land in fallow. Swamps, other wastelands, forest reserves and the like--commonly called "bush," but not available for smallholder agricultural production--are not treated in the model.

Although the simplifying assumption has been made that palm does not compete with cocoa in Sector 1, there is a significant level of wild palm production there. The model handles this by including wild palm in the Cocoa Sector as a proportion of the bush. It is further assumed that the wild palm is uniformly distributed therein, and any land leaving or entering the bush category does not change the proportion of bush that is wild palm. This treatment applies only to the Cocoa Sector; wild palm in the Palm and Rubber-Palm Sectors, where it is the major, or one of the major, productive enterprises, is included in the traditional palm perennial population streams.

Other Land Uses

No further possible land uses are considered in the model. Alternative perennials (such as citrus, coffee and kola), nonstaple foods (such as pineapple, banana, plantain, beans and green vegetables), and more than one cash annual alternative are ignored Such simplifications, necessitated by our resource constraints (principally data and computer storage, are justified by the relative economic insignificance, current and potential, to the agricultural economy of southern Nigeria. Further research will be necessary either to confirm this judgment or to expand the model to treat the potential production of more commodities.

Alternatives

In principle, every current land use is a conceivable alternative to every other present use in the same ecological zone. In practice, however, certain behavioral assumptions will reduce the myriad alternatives to be considered and simplify the model.

Table 5.1 displays the present uses and the alternatives considered to each. The last column shows the planning horizons relevant to each alternative. The second column in Table 5.1 lists the conceivable alternatives that we have "assumed away." While some of these assumptions are quite reasonable (for example, it may be safe to assume that modern cocoa will not be cleared and replanted with traditional varieties; or that traditional cocoa will not be cleared and the land planted directly in food), others may bear closer scrutiny and possibly may have to be reconsidered, especially if they unrealistically constrain the land allocations.

Decisions

Land use decisions depend on the relative profitability of each alternative, modernization promotion efforts, diffusion effects, the availability of land and capital, and the behavioral characteristics of the farmers making decisions.

TABLE 5.1
Alternative Land Uses.

Present Use	Alternatives Omitted	Alternatives Considered	Planning Horizon
1. Traditional perennials	a. Food b. Traditional replanting *c. Traditional new planting of the other perennial	a. Improvement b. Modern replanting *c. Modern new planting of the other perennial d. Abandonment to bush	Remaining life to 30 years 30 years 30 years Remaining life to 30 years
2. Modern perennials	a. Food b. Traditional replanting c. Modern replanting *d. Traditional new planting of the other perennial *e. Modern new planting of the other perennial	a. Abandonment to bush	Remaining life to 30 years
**3. Cash annual (tobacco)	--	a. Food b. Abandonment to bush	1 year 1 year
4. Food	a. Traditional new planting of the 1st perennial *b. Traditional new planting of the 2nd perennial c. Abandonment to bush (other than fallow)	a. Modernization of food b. Modern new planting of the 1st perennial *c. Modern new planting of the 2nd perennial **d. Cash annual (tobacco)	1 year 30 years 30 years 1 year
5. Bush	--	a. Traditional new planting of the 1st perennial *b. Traditional new planting of the 2nd perennial c. Modern new planting of of the 1st perennial *d. Modern new planting of the 2nd perennial e. Food **f. Cash annual (tobacco)	30 years 30 years 30 years 30 years 1 year 1 year

Perennial alternatives do not apply to Sector 4.
* Alternatives with one asterisk (*) apply to Sector 3 only.
** Alternatives and present uses with two asterisks (**) apply to Sector 4 only.

Figure 5.5 diagrams how these considerations, discussed in detail below, determine land use patterns.

Profitabilities

Farmers' decisions among the alternative land uses are based upon their perceptions of the <u>relative</u> profitabilities (Equation (L4)) of the available alternatives. Land use profitabilities are defined as the maximum average annual net returns which farmers can expect to receive over some relevant planning horizon. (See the last column in Table 5.1.) The model computes (Equation (L5)) the sum of the discounted present value of returns to a land use from the present to each year up to the planning horizon. The maximum annual average so obtained is the "profitability" of that land use.

In general, comparing the discounted present value of the total future returns accruing to an alternative (for instance, new planting of a modern perennial) with that of a present use (food) would be meaningless in view of the fact that each is based on a different planning horizon. In this case, the planning horizon for new planting is 30 years, while that of continuing with food production (an annual crop) is only one year (see Table 5.1). To avoid this difficulty, we assume farmers are interested in the present value of the maximum average annual returns they can expect rather than the present value of all future returns over the entire planning horizon.

The discount rates used to compute the present value of future returns are behavioral parameters in the model. The discount rates for each alternative are different, the relative difference reflecting varying attitudes towards the adoption of the alternative land uses. It is assumed that the more risky and unfamiliar the alternative, the higher the discount rate. For example, discount rates for replanting are higher than for improvement of traditional perennials, while discount rates for planting annuals are lower than those for planting perennials. Continuing in the present use has the lowest discount rate.

Since we are concerned with the decision functions of farmers, the streams of future revenues and costs (Equation (L6)) used in the profitability calculations should reflect the farmers' expectations. Thus, the producer prices used here are five-year exponential averages of recent prices. These price averages are projected into the future with trend factors (Equation (L7)), which are also exponential averages of recent producer price fluctuations. The form and computation of producer price averages and trends are discussed more fully later in the description of the price-generating component of the Southern model. Similarly, the stream of yields farmers expect are the yields they currently experience rather than the potential production reported by experiment stations. Actual yields can approach their potentials with time as farmers gain experience. This concept will be discussed more fully later in the AMPPAP component description. Additions to expected revenues are any cash and/or price subsidies which may be offered as part of a modernization program.

The cost side includes as technological coefficients biological, chemical, labor and capital (tools and equipment) input requirements over the planning period. Associated input prices, including the wage rate, are in the model as exogenous constants.

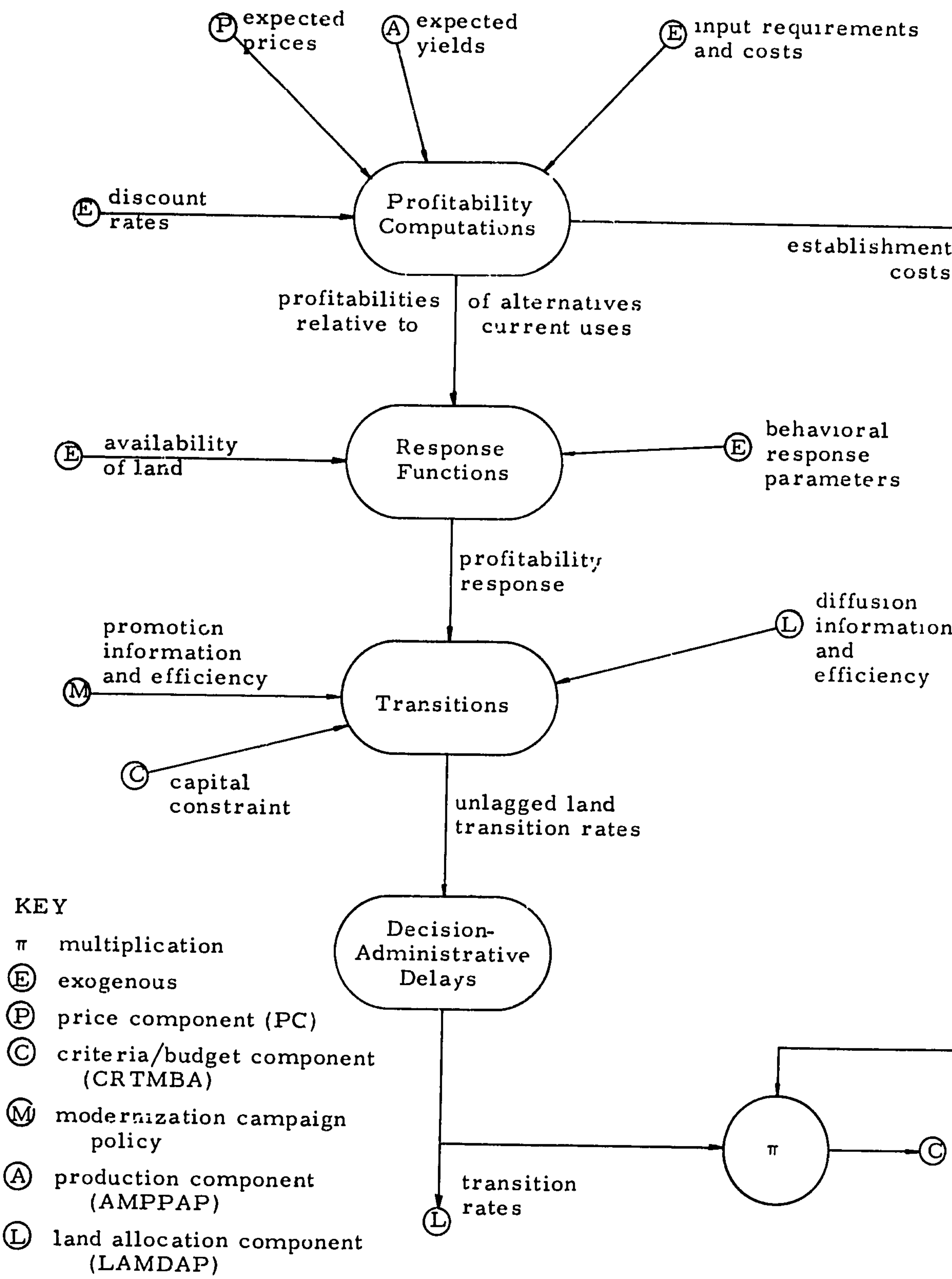


Figure 5.5. Diagram of land-use decision mechanism.

Information Units

In estimating the profitability differentials of the various alternatives, the farm decision makers require certain informational inputs. These include information on future producer prices, expected yields for modern cocoa, government or private subsidy and loan programs and expected costs. The model provides this needed information through "information units."

We introduce the general concept of an information unit so that various possible alternative means of disseminating information and promoting production campaigns can be considered. Of course, extension agents will be the main form of promotional information units. (In fact, diffusion and promotion information are both modeled in units of extension agent equivalents.) But, radio broadcasts, film showings and newspaper coverage also can be used by both government and private agencies. Newspapers and other printed matter are at present not the most effective media; however, as literacy rates increase, these media may become more significant in Nigeria.

While promotional information units (extension agent equivalents) are endogenously generated as a policy (see below in the policy component description), the model also computes (Equation (L8)) diffusion information units to represent the demonstration effect of farmers learning from one another about alternative land uses. The demonstration effect of an alternative to a present land use depends on the amount of land in each use. If there is no land in either, no diffusion information units are generated. This interaction effect is greatest when there is as much land in the alternative use as in the present use. Thus, the rate at which diffusion information units are generated reflects the s-shaped curve of diffusion theory (Rogers, 1962).

Availability of Land

Several factors contribute to determining the proportion of land in a present use which would be suitable for a particular alternative use, i.e., land available for a particular decision. The major factor derives from the imperfect homogeneity of the crop sectors (discussed earlier). The consequences of this are that in considering the alternatives to a present land use (Table 5.1), not all the land in the present use will necessarily be available for transition to a given alternative (Equation (L9)). Consider the Cocoa-Food Sector as an example. Not all food land is suitable for cocoa, nor is all traditional cocoa land even suitable for replanting. Soil and rainfall conditions in certain Amelonado cocoa areas, for instance, may not be good for Upper Amazon cocoa. Another factor, a policy one, may dictate that the proportion of land available for a particular alternative use will be different for land transferring due to promotion campaigns rather than by diffusion effects. Modernization program policies could be rather restrictive as to soil conditions, local road conditions, farmer experience, etc., in allowing farmers to enter the program, whereas such limitations will not exist for the diffusion effect.

Perennial land uses have a further restriction--a behavioral one--affecting the proportion of land available for alternative uses. It is assumed that land will not leave a perennial use in some stages of production (Equation (L10)). For example, farmers will not remove traditional cocoa trees in the stage of maximum yields. Obviously, such behavior should not be assumed but rather be a result of economic decisions. However, simulating this decision for each cohort of each perennial population stream would vastly complicate and enlarge the model. Therefore, the decisions are modeled for each perennial stream in its entirety, and land leaves each cohort in the same proportion as that cohort's proportion of the total population of those production stages which are available for transition.

Finally, there is a special restriction on how much bush land can be put to other uses. This restriction stems from the fact that "bush," as defined in the model, includes fallow land, both short-cycle and long-cycle. An amount of bush land (Equation (L9)), representing short-cycle fallow which farmers expressly reserve to maintain subsistence food production yields in future years, is considered not available for other uses.

Transition Response

Changes in land use patterns reflect farmer responses to the perceived profitabilities of the available cropping alternatives. The assumption is made that the most profitable alternative is likely to be the first choice of most of the decision makers, and so on, in order of decreasing profitability.

The profitability response function (Equation (L11)) determines how many acres of land an information unit (either extension agent promotion or diffusion effect) can "convert" per year from one use to another. This calculation depends on the profitability of the alternative, the efficiency of the information unit (see below), the land available for transition and the behavioral characteristics of the farm decision makers. (See Figure 5.6.)

The efficiency of an extension agent (the same holds for a demonstration unit) is the maximum number of acres he is able to convert in a year as the profitability of the alternative grows. Figure 5.6 shows that the response function actually computes the proportion of that efficiency (profitability response) which can be attained for a given profitability. The maximum proportion

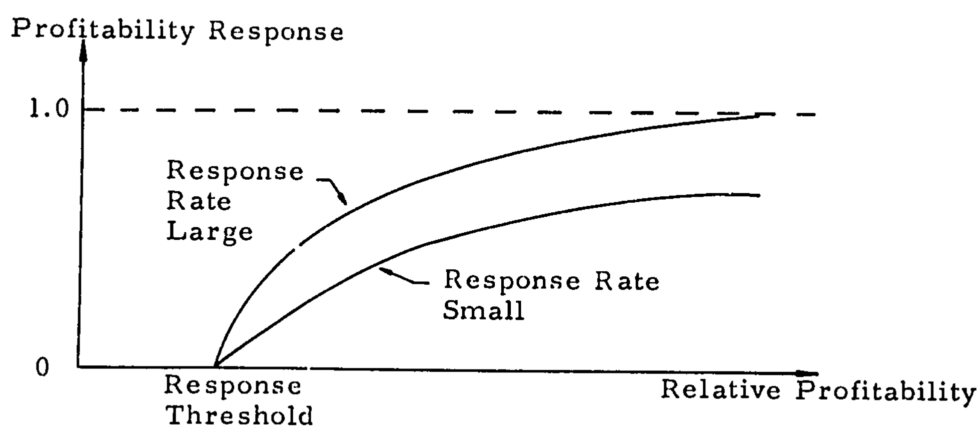


Figure 5.6. The profitability response function.

is, of course, 1.0; however, if there is a land constraint (Equation (L12)), the maximum attainable will be something less than the potential efficiency.

The threshold and response rate parameters shown in Figure 5.6 reflect the farmers' attitudes and behavioral characteristics which affect the rate of their response to the relative profitabilities of the various alternatives facing them. The factors represented by both of these parameters include, for instance, the degree to which the trees are fixed assets, risk aversion, the amount of inconvenience the farmers may see in an alternative use (including the extent and quality of roads and the transport system), farmers' attitudes towards government programs and promises in general and the land tenure system. The threshold parameter of an alternative marks the point (relative profitability of the alternative to a current use), below which there will be no transition to that alternative. Since farmers' attitudes towards extension agents (or other promotional efforts) will differ from those towards one another, the values of these parameters may be different for promotion responses and for diffusion responses.

The transition rates (Equation (L13)) are constrained by available capital and lagged to account for decision-making delays and delays involved in program administration and distribution of necessary inputs and subsidies (in the case of externally promoted alternatives). The capital available for investment in alternatives in an ecological zone includes capital generated endogenously as income (after allowing for consumption) and potential credit, which in turn depends on the capitalized value of cultivated land. The availability of capital and credit will be discussed more fully in the discussion of the criteria and macro-budget accounting component. Any capital constraint in a crop sector is applied uniformly to all alternative land uses in that sector.

The demand for capital--which is compared (component CRTMBA) with available resources to determine if capital is a constraint--is merely the sum of the establishment costs (Equation (L14)) incurred by the decisions to move land to alternative production uses. The establishment cost of an alternative is defined as the <u>net cost</u> which would be incurred in the first year of the establishment of an alternative. This cost will include such items as tools, biological and chemical materials and hired labor necessary for land clearing and planting. This definition of establishment cost is used--rather than total net costs over the planning period until positive net revenues occur or, alternatively, until production begins--so the capital required <u>in the year the transition is made</u> can be compared with what is available that same year. Since this is the major cost which would have to be met with either credit or the currently available cash flow, it would be the primary financial constraint to production enterprise changes. Costs incurred over the remainder of what might be called the establishment period are included as operating expenses computed in component AMPPAP.

In addition to capital resources, demands for modern inputs generated by farmer responses to the modernization programs are computed (Equation (L15)). These include biological inputs, such as new hybrid seedlings and other planting materials, and chemicals, such as fertilizers and sprays.

A final economic decision to be made is whether some perennial land is to be abandoned <u>indefinitely</u> (as opposed to a short-term abandonment discussed in the next section as a price response), thus reverting to bush. Such an abandonment decision would be made, for example, if producer prices fell to such a low level that farmers' opportunity costs (land and labor) of maintaining the current production capacity of the perennial became too great. Figure 5.7 shows how the model (Equation (L16)) handles this decision. If the production of a given perennial is profitable enough (see the discussion above and Equation (L5) for a definition of profitability), essentially no abandonment will occur. On the other hand, once the profitability drops below a threshold value (which may be positive, negative or zero, depending on behavioral characteristics particular to a given perennial commodity or to farmers) abandonment will occur at an increasing rate up to a maximum, as the profitability continues to fall.

Noneconomic Responses

In addition to the economic land use decisions described so far, the number of acres cultivated will increase as the number of decision makers increases with the population. The economic decisions discussed above represent the activities of established farmer decision makers, i.e., whether to increase or decrease the amount of land cultivated or whether, and how, to shift land currently in production to alternative uses. Those young men coming of age and starting new farms of their own, on the other hand, will not make that economic decision. Constrained by the available bush land (Equation (L20)), and as long as there is at least a positive profitability (Equation (L19)), new land comes into production (Equation (L17)) at a rate proportional (Equation (L18)) to the rate of increase in the number of decision makers. If there is an economic or land constraint, then those new farmers not acquiring land of their own will wait until conditions are more favorable, adding to the pressure of new decision makers for land (Equation (L21)). This pressure would be a significant factor to consider if rural-urban migration is to be determined endogenously in the model. (See Chapter VI.)

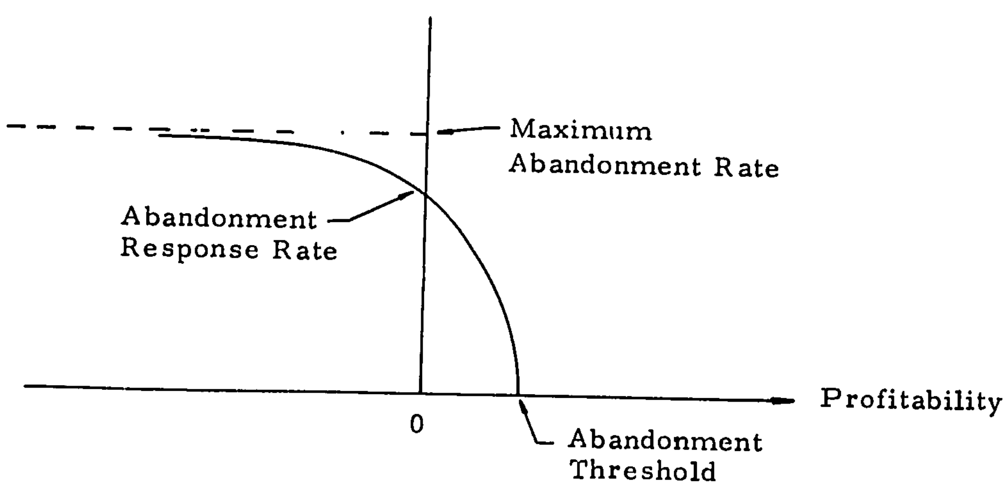


Figure 5.7. The abandonment response.

Summary

Component LAMDAP allocates land to alternative production uses among perennials and annuals. Included in these alternatives are the modernization options promoted exogenously. These land use decisions are based on the discounted profitabilities of alternatives relative to current uses. The discounting depends on farmers' expectations regarding prices and yields, while the decision responses are determined by such behavioral characteristics as risk aversion and confidence in outside information sources. An essentially noneconomic expansion of cultivated land also takes place as the number of farm decision makers increases.

Agricultural Marketing, Production and Processing--

Annuals/Perennials (AMPPAP)

Component AMPPAP, before generating the production, processing and marketing of the six agricultural commodities (cocoa, palm oil, palm kernels, rubber, food and tobacco), determines the food subsistence level of the population in each ecological zone (crop sector) and the yields of the various commodities.

Subsistence Level

Of the staple food produced in each crop sector, one portion is consumed directly by the agricultural population of that sector while the rest goes through the cash food market. The portion retained for subsistence consumption is determined by the total demand for calories in the agricultural population and the proportion of that demand met by subsistence food (the remainder being purchased in the cash food market). The assumption is that the subsistence level proportion is not necessarily 1 (total subsistence), but may be less depending on conditions in the food market and the cash income generated from the cash crops. Since the cash crops, and thus the degree of dependence on the cash economy, differ across the crop sectors, the subsistence level is sector-specific.

Farmers will change their desired subsistence level depending on the degree of stability in the cash food market, on the food price level and on the income from cash (primarily export) crops. Instability in the food market will tend to increase a farmer's reliance on his own efforts for his food needs; i.e., the subsistence level will go up. This effect on the subsistence level is generated by the magnitudes of the relative food price changes (up or down) summed for the three preceding years (Equation (A1)).[3/] This assumes farmers have a three-year memory regarding the effect of market food prices on market stability.

Perfect stability in the food market, however, is not enough to lower the subsistence level. The second factor determining changes in the level of subsistence is represented as the ratio of the value, at market prices, of the food consumed by the agricultural population to the net revenue from cash crops (other than cash food). This formulation (Equation (A2)) incorporates as a factor the food price level rather than price changes. However, the price level must also be related to the cash revenue farmers have available to purchase food in the market and to how much food would have to be purchased to meet the demand for calories.

3/ See Appendix V.B, page 192 for an exposition of the equations.

Decreases, for example, in the food expenditure/cash revenue ratio--due to falling food prices, rising producer prices for cash crops or falling costs in cash crop production--will tend to decrease the subsistence level, i.e., increase producer reliance on the food market for their caloric needs. Equation (A3) combines these two factors (food market stability and the food expenditure/cash revenue ratio) to determine the subsistence level in each crop sector.

Yields

There are three determinants of commodity yields. First, provision is made in the model for yields to increase spontaneously, i.e., independently of outside influences, as farmers gain production experience. We might call this a learning-curve yield response. Second, the yields of the substreams4/ are combined, weighted by the amount of land in each substream, to obtain an average yield for each cohort4/ (in the case of perennials) of each stream. Finally, commodity yields are adjusted to account for a short-run supply response to the current producer prices. Each of these factors will now be discussed in detail.

Learning curves for the perennial and food yields serve two functions in the model. Since we are interested in keeping the definitions of "modernization" and "modernizing programs" as rigid as possible in order to evaluate these programs, the learning curve allows us to simulate past behavior which included spontaneous adoption, to a limited degree, of certain modern methods and inputs. For simulation runs including modernization programs, the learning curve also allows us to simulate behavior, whereby farmers, in adopting modern methods and inputs, do not immediately achieve the maximum potential yield of the crop. Initially, modern land will not be yielding its potential, but this yield will increase over time towards that potential as farmers gain experience with the new methods and materials. Since this learning behavior represents a diffusion phenomenon, i.e., farmers learning from one another, the learning-curve effect (modeled by Equation (A4)) will not take place unless a minimum number of acres in a particular use has been surpassed.

After the learning-curve adjustment, the yield of each crop is averaged across land use substreams, i.e., traditional and modern food, newly planted and replanted modern perennials, and traditional and improved traditional perennials.5/ In calculating this average (Equation (A5)), the yield of each substream is weighted by the proportion of the crop land in that substream.

The proportion of the total capacity (acreage) of a commodity actually harvested is a function of that proportion under "normal" producer price conditions (a behavioral parameter) and the ratio of the current price to the normal price. The normal price is taken to be an exponential average of past producer prices. The model (Equation (A6)) incorporates behavioral parameters which can generate negatively sloped, positively sloped, or perfectly inelastic supply curves.

4/ *These terms are defined above in the discussion of the land allocation and modernization component.*

5/ *These terms are defined above in the discussion of the land allocation and modernization component.*

Finally, while the harvest response is a short-term response, the input response is medium-term. In perennial crop production, farmers may put forth less harvest effort (as we have seen above) in response to unfavorable prices. However, they may also cut back on some cultivational practices, particularly in the case of modern production. The practices which may be affected include weeding, spraying, fertilizer application and similar modern techniques. The cut-back, in the application of these practices, albeit temporary, will result in reduced yields later--say, one to three years. This deferred yield effect is a factor contributing to the determination of the yield actually attained (Equation (A6)) in any given year.

Food Production

In computing food production, AMPPAP first calculates (Equation (A7)) the food land necessary to meet the subsistence demand of the agricultural population. A constraint is placed on the total food land in production so that it at least covers what is necessary to produce subsistence food. Any remaining food land goes for cash food production. Subsistence and cash food production, then, is simply the product of the food yield and the land in production (Equation (A8)). Added to the cash food produced is the staple food intercropped on land in perennial crops in the gestation stage.

Perennial Production

The production of each perennial population stream--traditional cocoa, modern cocoa; traditional palm and modern palm in the Palm Sector; traditional rubber, modern rubber, and traditional palm and modern palm in the Rubber-Palm Sector--is computed (Equation (A9)) simply as the sum of the output (yield times acres) of each producing cohort of that stream. The outputs of streams of like commodities, e.g., traditional and modern cocoa, are then added to get production by commodity, i.e., cocoa, palm and rubber.

Marketing

Simple accounting equations model the marketing and processing of the agricultural output. The marketing of each commodity is represented by proportions of marketable output (Equation (A11)) going to processing, domestic consumption or export. These proportions are fixed parameters which characterize the place of each commodity in the domestic economy, i.e., how much of it is processed domestically (either before consumption or before export), how much is consumed domestically and how much is exported. The marketable output is the portion of the total production of a commodity (Equation (A10)), which is neither consumed on the farm nor lost (due to spoilage or waste) between field and market.

Processing

Of the commodities produced in southern Nigeria, palm fruit, rubber latex and raw tobacco are processed (in the model) into palm oil, palm kernels, rubber sheets and cured tobacco. The production of cocoa and food is assumed to include any processing performed on those commodities, e.g., drying the cocoa beans or making gari from cassava.

The capacity of the processing industry for each commodity, i.e., the physical limit on the amount that can be processed at a given time, is a function (Equation (A12)) of the raw material input. The assumption is made that the nature of agricultural processing methods allows enough flexibility for total capacity to exceed raw material input even when that input may be rising. Total capacity will decrease if excess capacity, exponentially averaged over the last few years (Equation (A13)), exceeds some critical value (say, 60 percent). Rather than overt dismantling or disinvestment, replacement investment ceases until a desired (lower) level of capacity is attained (Equation (A14)).

While the model focuses principally on the modernization of agricultural production, there may be significant benefits to the agricultural economy (primarily since agricultural producers essentially do their own processing, either as individuals or in cooperatives), by increasing processing efficiency and/or improving the quality of processed commodities. Modern processing capacity can be generated (Equation (A15)) by exogenous (policy) modernization investment. Once modern capacity has been so determined, the remainder of total capacity will be provided by traditional facilities (Equation (A16)). Thus, modernization of processing means (here) the conversion of traditional capacity to modern, rather than the creation of new capacity.

Replacement investment in traditional and modern agricultural processing is assumed to equal depreciation of the capital stock (Equation (A17)), while net investment is the investment required to change capacity. Investment in traditional processing is computed endogenously in the model (Equation (A18)) as the replacement and net investment which must take place to generate the traditional capacity. Modern investment is similarly determined if capacity is totally modern (and thus, there is no more traditional capacity to convert), or the exogenous policy input ceases.

Each raw material input, after being constrained by the available capacity and reduced by the amount of processing loss and waste (Equation (A19)), may be processed (Equation (A20)) into one or two commodities. For example, rubber latex becomes sheets, while palm fruit is converted to oil and kernels. The loss and output proportions may be different for modern and traditional processing, so a weighted average (Equation (A21)) of the modern and traditional proportions is used. Processed output is either consumed domestically or exported (Equation (A22)). In the case of palm oil, the domestic demand is computed, and any excess is exported (Equation (A23)).

The model deals only with smallholder production. Therefore, it is necessary to include a mechanism to generate the output of rubber plantations and estates. (Rubber plantations are assumed significant enough to require this, whereas palm estates are totally ignored in the model.) Thus, an exogenous growth of the output of rubber estates (Equation (A24)) is modeled.

Input Demands and Accounting

Finally, component AMPPAP computes the input demands and performs the macro-economic commodity accounting for agricultural production, processing and marketing. Labor demands by commodity and by crop sector are computed (Equation (A25)). Capital, chemical and biological input demands are calculated (Equation (A26)) for the production of each commodity. Labor, capital and chemical inputs necessary for processing are also determined (Equation (A27)), as is the labor required to market each commodity.

A note is in order here about two factors affecting wages paid and cash revenues (Equation (A28))--the proportion of labor which is hired and the proportion of marketed output which is sold. First, the proportion of agricultural labor hired for the production of each commodity reflects two concepts (Equation (A29)). One is the extent to which nonfamily (hired) labor is employed to maintain and harvest a commodity. This will differ from commodity to commodity depending on the farmers' attitudes towards each--attitudes such as trust in nonfamily workers with a given commodity and the social desirability of a particular type of work, e.g., rubber tapping. Assuming that labor is not a constraint, as this model does, any positive excess demand for agricultural labor is met by labor from outside the region, i.e., seasonal migration from the North. Such hired labor is arbitrarily assigned to each commodity in proportion to the commodity's total labor usage.

Second, the quantity of output sold on the market (Equation (A30)) depends on the ratio of demand to supply. If there is excess demand, everything is sold. For the major cash crops--cocoa, palm, rubber and tobacco--demand is assumed to equal supply; that is, Nigeria can sell all it wants on the export market, and the Nigerian Tobacco Company buys all the tobacco produced. It is only for food, the demand for which is endogenously generated in the population component, that supply may exceed demand.

Accounting is carried out for agricultural production and marketing (Equation (A28)) and processing (Equation (A31)) to compute wages paid, cost of inputs, subsistence revenue in kind, cash revenue, value added, net revenue (income), taxes paid, profits, returns to labor and land and capitalized value of land for each commodity (and totaled across commodities). Most of the agricultural processing in Nigeria is performed by the producers themselves, either as individuals or in cooperative ventures. Therefore, the portion of processing revenues returning to the agricultural sector is computed (Equation (A32)) so it can be included as agricultural income available for investment in production or for consumption (see component CRTMBA).

Summary

In summary, AMPPAP simulates the production, processing and marketing of agricultural commodities for southern Nigeria. In doing so, it determines commodity yields and the agricultural population's subsistence level. In addition, AMPPAP generates input demands and macro-economic performance criteria for use by other components of the Southern model and the national model.

Price Generation (PG)

Component PG services the rest of the Southern model by generating world prices for the export commodities and market, processor and producer prices of all five commodities considered--cocoa, oil palm products, rubber, food and tobacco. In addition, five-year exponential averages of the producer prices and price trends are computed for use by component LAMDAP in the profitability calculations for the land allocation decisions and by component AMPPAP in the determination of the supply response of yields.

Figure 5.8 marks the progress of commodities from the producer to the consumer, i.e., producer → processor → domestic market → (for export commodities) world market. Thus, costs (including taxes) are passed on down the line. At the top, world prices are exogenously generated (Equation (P1))6/ and market prices for the export crops, i.e., prices received by the marketing boards where these exist, are simply world prices less export taxes (Equation (P2)).

The market price of palm oil is constrained (Equation (P3)) to be the maximum of the marketing board's price as determined from the world price and a domestic price which depends on the internal consumption of palm oil as computed in component AMPPAP (Equation (P4)). The market price for food is computed endogenously in the interregional trade component of the national model, while that of tobacco is set exogenously to reflect the price received by the Nigerian Tobacco Company.

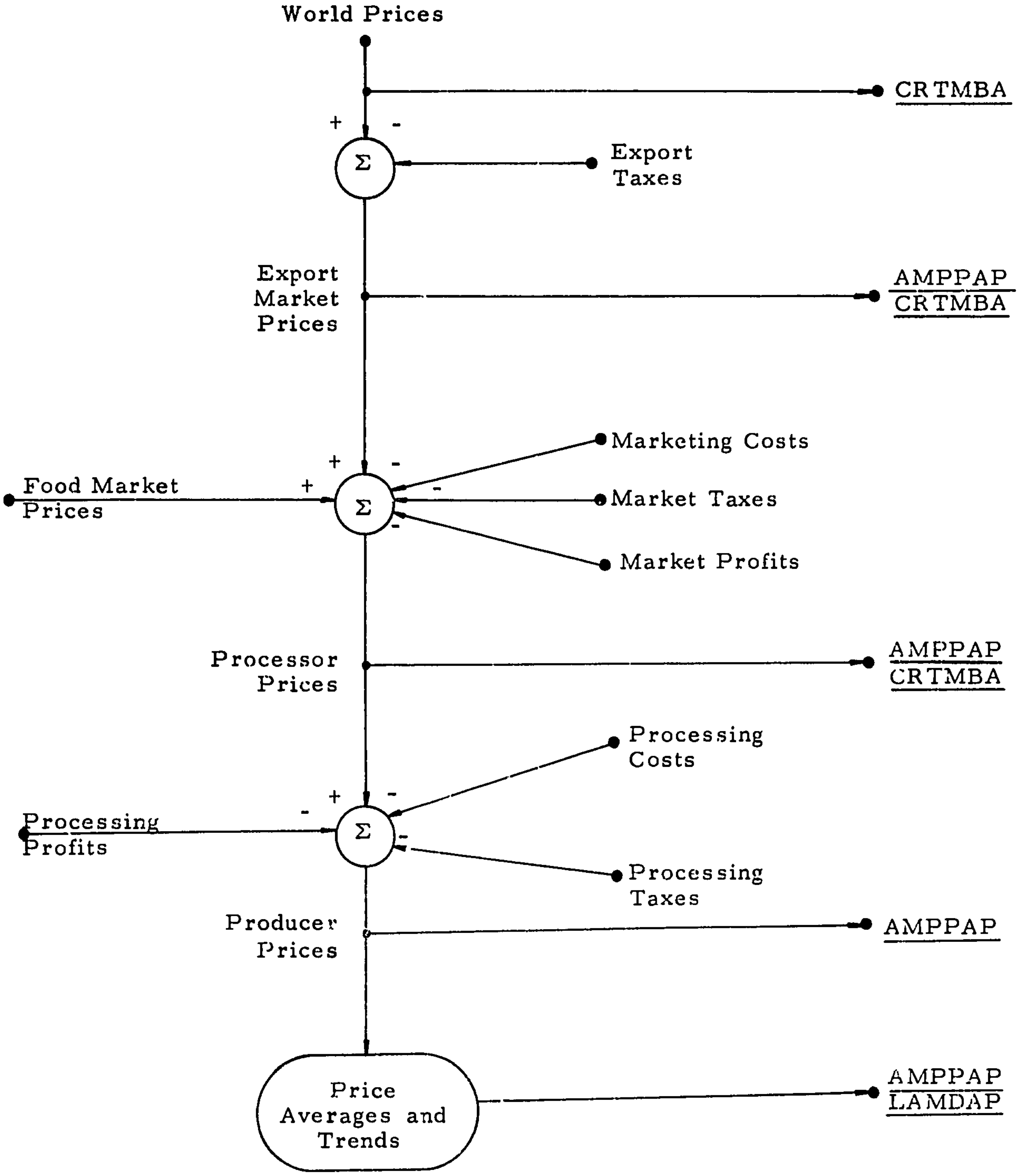
The next price computed (Equation (P5)) is the price to the processor for those commodities whose processing is explicitly modeled,7/ namely, palm oil, palm kernels, rubber and tobacco. For cocoa and food, the prices computed here will be the producer prices. These are the market prices less marketing costs, taxes and profit surplus. For the commodities marketed through marketing boards, the profit surplus represents the marketing board tax policy. Again, the palm oil price is handled differently (Equation (P6)), recognizing the domestic as well as export markets. In this case, the actual price to the processors of palm oil is a weighted average of the processor price set by the marketing board and the price from domestic marketers, where the weights are the proportions of oil exported and consumed internally, respectively, and where the domestic marketing costs and profit surplus are assumed to be the same as for the marketing of food.

Palm, rubber and tobacco producers receive the processor price less processing costs, taxes and profit margins (Equation (P7)). For palm products, oil and kernel prices are averaged together so that producers are paid for palm fruit bunches.

For the purposes of land allocation decisions (component LAMDAP), and harvest price responses (component AMPPAP), producer prices and price trends are exponentially averaged (Equation (P8)). In recognition of the fact that some, if not all, of the processing may be done either by farmers themselves or farmer cooperatives (processing profits thus going to the agricultural sector accounts), the price used in the exponential average is weighted between the producer price and the processor price, where the weight is the proportion of processing performed by the agricultural sector (Equation (P9)).

6/ *See Appendix V.B, page 214 for an exposition of the equations.*

7/ *See the description of component AMPPAP.*



Key to components using the various prices:
AMPPAP - Agricultural marketing, production and processing--annuals/perennials
CRTMBA - Criteria and macro-budget accounting
LAMDAP - Land allocation and modernization decisions--annuals/perennials

Figure 5.8 The price generation component.

World, market, processor and producer prices and the price averages so generated by component PG are then used by other components of the Southern model to determine the allocation of land, the production of the various commodities and the resulting incomes, taxes and other accounting criteria.

Policy Entries

Since this is a policy-oriented model, there are a number of places in which the policy maker can enter the simulated system to perform experiments. Two primary classes of experiments may be conducted. One involves changing system parameters and technological coefficients to see the effect on the model's performance. The other class includes actual policy trials. Simulation runs testing parameter sensitivity and conducting policy experiments with the Southern model are discussed later in this chapter, while model tests and policy runs on the total Nigerian model are presented in Chapter IX.

Parameter Sensitivity and Policy Making

Briefly, two purposes may be served by changing the values of system parameters and/or technological coefficients. First, the policy maker may feel the values of some of these parameters are not realistic, or he may be unsure as to what they should be. By entering values he judges to be more realistic, he will be able to compare the effect of different parameter values on the simulated behavior of the system. If system behavior is insensitive to changes in some parameter, the policy maker need not concern himself further with that parameter. On the other hand, a parameter which does significantly affect system performance would play a role in future policy-planning decisions. Second, it would be possible to evaluate likely consequences of investments in alternative areas of research, e.g., the development of high-yielding hybrid varieties, or research into the use of chemical sprays and fertilizers, by making corresponding changes in the relevant technological coefficients, i.e., per-acre yields, labor-input requirements, or other input requirements and costs.

Policies

Three basic policy points are structured in the simulation model. Policies may be set and experimented within any one or combination of the following areas: production campaigns, marketing board pricing policies and tax policies.

Production Campaigns

The same modernization executive component used in the Northern model (Chapter IV) is used in the South to allocate a modernization budget among up to five production campaigns. This budget is used to generate the promotional information units (particularly extension agents) discussed earlier in the description of component LAMDAP. Cash and price subsidies, technical assistance to farmers entering the campaigns and campaign overhead expenses are also paid out of the modernization budget. Table 5.2 lists the 17 possible production campaigns; any five may be considered in the Southern model at a time. The table also defines what is implied in the three classes of campaigns--improvement, replanting and new planting.

TABLE 5.2
Production Campaigns.

Campaigns:

1. Cocoa improvement
2. Cocoa replanting
3. Palm improvement (Palm Sector)
4. Palm replanting (Palm Sector)
5. Rubber improvement
6. Rubber replanting
7. Palm new planting from rubber
8. Palm improvement (Rubber-Palm Sector)
9. Palm replanting (Rubber-Palm Sector)
10. Rubber new planting from palm
11. Cocoa new planting from bush/food
12. Palm new planting from bush/food (Palm Sector)
13. Rubber new planting from bush/food
14. Palm new planting from bush/food (Rubber-Palm Sector)
15. Food modernization (perennials sectors)
16. Food modernization (annuals sector)
17. Tobacco new planting from bush/food (annuals sector)

Definitions:

1. Improvement of perennials: the application of modern inputs--e.g., fertilizers, sprays--and improved methods of managerial control--e.g., weeding, spacing, tapping--to traditional biological varieties.

2. Replanting of perennials: replacing traditional varieties with modern hybrids--e.g., higher-yielding, disease resistant--and applying modern inputs and cultivational practices.

3. New planting of perennials: planting modern hybrid perennials on bush or food land (or replacing another perennial commodity) and applying improved methods.

4. Modernization of food: introducing improved varieties and/or methods into staple food crop production.

5. New planting of tobacco: introducing tobacco (or some other cash annual), presumably under modern production.

Associated with these production campaigns is the policy determination of the eligibility requirements placed on farmers and land entering the modernization program. In the case of farmers, these requirements might include a particular level of experience and/or financial resources, while land could be constrained by soil conditions and contiguity requirements. These policy considerations are roughly aggregated in the model by the concept of land availability discussed above in component LAMDAP.

Marketing Boards

The second major policy area which can be investigated with the model is the area including marketing board pricing policies. With simulation runs incorporating different levels of marketing board surpluses for each commodity, questions can be answered regarding the likely consequences these policies will have on production levels, foreign exchange earnings, agricultural income and other relevant economic performance criteria.

Taxes

Finally, the model allows experimentation with several kinds of taxing policies. Specifically, income taxes can be set on agricultural producers, processors and marketers, respectively, and profit taxes can be levied on agricultural processors. In addition to these, different levels of export taxes can be experimentally tested on the various agricultural export commodities.

Criteria and Macro-Budget Accounting (CRTMBA)

The major exit points of the Southern model are located in component CRTMBA. These include economic and accounting criteria and the agricultural sector budget.

Performance Criteria

The economic variables computed here include value added in agricultural production, marketing and processing (Equation (C1)),8/ the value of agricultural exports at F.O.B. and processor prices (Equation (C2)) and government revenues (Equation (C3)). Government revenues are composed of taxes on agricultural incomes and profits, export taxes and marketing board net revenues. Also computed are marketing board overhead costs. In addition, all these quantities are accumulated over the course of a simulation run. Other variables computed (Equation (C4)) and fed back to the national and nonagricultural sector model (Chapter VII) are: (1) export taxes and (2) the value of chemical and capital inputs demanded for agricultural production and processing. Finally, total demands for investment capital in the crop sectors (defined in component LAMDAP, Equation (L14)) and total demands for chemical, biological and capital inputs generated by the various production campaigns are computed (Equation (C5)).

Budget Accounting

In order to determine agricultural consumption and investment, component CRTMBA computes disposable income in the agricultural sector. This includes disposable income from production and processing performed by the agricultural sector. This macro-budget accounting is performed for each ecological zone (or crop sector), since investment and consumption decisions depend on the alternative income-generating activities facing the farmers. Therefore, the production and processing revenues and expenditures computed by commodity in component AMPPAP are distributed here by crop sector. Revenues include the gross cash income

8/ See Appendix V.B, page 218 for the equations.

derived from the sale of commodity outputs, disposable income to the agricultural sector from agricultural processing (discussed below), and credit payments from outside the agricultural sector. Expenditures are the costs of chemical, biological and capital equipment inputs and income tax payments, as well as cash food purchases and debt service and interest payments.

The apportionment is done (Equation (C6)) by assigning to each crop sector the revenues and expenditures of each commodity in proportion to that sector's contribution to the total output of the commodity. This distribution scheme, while not ideal, is not too far off the mark since commodity revenues and expenditures are directly proportional to output and since the constants of proportionality (commodity and input prices), are assumed to be uniform throughout the South. Output, in turn, is directly proportional to land, which is distributed by commodity in each ecological zone. However, the proportionality constants in the latter case, namely yields, may differ from crop sector to crop sector. For example, if a modernization campaign in palm production has been going on in the Palm Sector (Sector 2), palm yields there will be higher than palm yields in the Rubber-Palm Sector (Sector 3).

A portion of the agricultural sector's consumption expenditures remains within the agricultural sector itself and, hence, is treated (Equation (C7)) as additional agricultural income. These internal consumption expenditures are for cottage industries and other economic activities of the agricultural population apart from the production and processing of agricultural commodities.

The outstanding debt in the agricultural sector is the time integral (Equation (C8)) of credit payments to the sector less the debt service. The assumption is made that a fixed proportion of the debt is repaid each year. This may be treated as government (or other lending agency) policy or simply a behavioral characteristic. It is further assumed that interest is not allowed to accumulate. Rather, interest charged against the outstanding debt is paid each year.

Disposable income in the agricultural sector is simply (Equation (C9)) the gross income minus the cost of nonfarm inputs (chemicals, equipment, modern biologicals), taxes, the debt service, interest payments, internal consumption expenditures and cash food expenditures. The last item assumes farmers will first feed themselves and their families before disposing of their income in other ways. Wages paid are not deducted since they remain within the agricultural sector as part of disposable income for consumption or investment. Disposable income is constrained to be at least enough to cover a subsistence level of nonfood consumption. Any shortage of actual income below this minimum consumption level is assumed made up by credits and added to the debt.

Consumption is determined (Equation (C10)) by the average propensity to consume, while the income available for investment is the disposable income minus consumption. If the demand for investment generated by the land allocation decisions (i.e., <u>net</u> investment; replacement investment--equipment costs--are treated as operating costs) the excess capital is added to consumption. If the demand for investment exceeds the available supply, a demand for credit from outside the agricultural sector is generated (Equation (C11)). This demand for credit is constrained by the availability of credit, which is a straight proportion of the equity value of cultivated land. Equity value is defined as the capitalized value of the land (computed in component AMPPAP) minus the outstanding debt.

If both the investment capital available from disposable agricultural income and the credit available from sources outside the agricultural sector do not meet the demand for investment, a constraint is placed on the land allocation decisions (as discussed earlier in component LAMDAP). The constraint is the ratio (Equation (C12)) of the available investment capital to the investment demand if this ratio is less than 1. The ratio is applied directly to the land transition response (Equation (L13), Appendix V.B). The constraint mechanism is purposely simple; however, if further evidence should indicate that this formulation does not sufficiently represent the actual capital constraint faced by the farm decision makers and its (the constraint's) consequences for agricultural investment patterns, the mechanism could be developed further. Indeed, it may be that this phenomenon cannot be fully incorporated in the model until the whole question of the distribution of income in the agricultural sector is modeled into the land allocation decisions and production responses.

The disposable income generated by agricultural processing (part of which is included with agricultural income) is computed (Equation (C13)) in a manner similar to the agricultural disposable income discussed above. The processing debt service, interest payments, operating costs, taxes and investments are subtracted from gross income to generate disposable income for consumption. It is assumed that a proportion of the processing investment (discussed in component AMPPAP) is financed by credits granted from outside the agricultural processing sector. These credits make up the processing debt. The portion of disposable income from processing which is added to agricultural income is proportional to the amount of processing done by agricultural producers.

Finally, the disposable income in the marketing sector (Equation (C14)) is simply marketing profits (defined in Equation (A26), Appendix V.B), plus wages paid in the marketing sector, plus the marketing board overhead. The last item assumes that overhead goes primarily for the salaries of marketing board personnel.

Summary

Component CRTMBA, then, computes performance criteria both as exit points of the Southern model and to be fed back to the national accounts/nonagricultural sector model. It also determines agricultural consumption and investment by balancing the agricultural sector budget.

Data Usage

Data for the Southern annuals/perennials model fall into three categories: system parameters, technological coefficients and initial conditions. The data requirements of each category number in the hundreds, and each class of data has its own particular needs and sources. Appendix V.C tabulates some of the more important data for each class and gives detailed source references. In this section, we will briefly discuss the three categories and their data sources.

System Parameters[9/]

System parameters are primarily parameters reflecting the behavioral characteristics of the system being modeled. Thus, in a sense, they, along with the structural equations, actually define the system. A few examples of the many system parameters of the Southern model are:

1. The land use profitability response parameters (THRLD, SHAPE in Equation (L11)),

2. The profitability discount rates (DR in Equation (L5)),

3. The many delays and averaging and smoothing lags of the model (e.g., PEXDEL in Equation (L17), SDEL in Equation (A7) and PRCDEL in Equation (P8)),

4. The subsistence level parameters (SLMIN, SLTHR, EFPSF in Equation (A3)),

5. The short-term supply response elasticities (SUPRSP in Equation (A6)),

6. The marketing distribution parameters (POMC, POMP, POMX in Equation (A11)),

7. The average propensity to consume (APC in Equation (C10)).

Little data exist on most of the behavioral system parameters. The kinds of field research necessary to estimate many of them have never been conducted. Values used in the early stages of building and testing the model were educated and intuitive "guesstimates." The education and intuition were acquired from the various CSNRD reports, Güsten, Federal Office of Statistics Rural Economic Surveys, interviews with Nigerian officials and farmers and a number of man-years of personal experience in Nigeria and other developing countries. Let us look at the land use transition response thresholds for traditional perennial land (THRT in Table 5.C.1.a) as an illustration. The values shown (0.2, 0.4 and 0.6) mean that the alternatives of improvement, replanting and new planting a different perennial (see Table 5.2) must be at least 20, 40 and 60 percent more profitable, respectively, than the traditional perennial crop currently on that land before farmers will transfer the land to the alternative use. The relative values hypothesize different farmer attitudes (e.g., risk aversion; see the above discussion of component LAMDAP) towards the three alternatives.

Parameters such as this one play an important role in the validation of the model in spite of the uncertainty as to their "actual" values. Some of them provide a number of degrees of freedom with which to tune the model to track historical time series and to adjust the model's behavior to conform, where appropriate, with the expectations of economic and social theory and of the intuitions and knowledge of people with experience in Nigeria. Others, as shown by sensitivity tests, are not crucial to the model's performance; i.e., changing the values of these parameters has little effect. These validation and testing procedures will be discussed more fully later in this chapter and in Chapter VIII.

9/ *See Appendix V.C for tabulated values of selected system parameters used in the Southern model.*

Technological Coefficients10/

Technological coefficients are perhaps the easiest to come by. Our principal sources for values of these parameters were several publications: FAO, 1966; Phillips, 1964; Güsten, 1968; Galletii, Baldwin and Dina, 1956; CSNRD reports: and project proposals of Nigerian federal and state ministries. The existence of data for these parameters does not mean there is either perfect confidence or general agreement on them. Further research and field work will be necessary to increase the level of confidence in the values given many of the technological coefficients.

Some examples of technological coefficients used in the Southern model are:

1. Commodity yields (YPER1, YPER2, YF1, and YF2 in Equation (A4)),
2. Labor input rates (PLA1, PLA2, PLY, FDLAB1, FDLAB2, and FDLABY in Equation (A25)),
3. Chemical input rates (PCA1, PCA2, FDCH1, and FDCH2 in Equation (A26)),
4. Input prices (PCI, PL, PLM, and PBI in Equation (A28)),
5. Processing capital/capacity ratios (PKCRT, PKCRM in Equations (A14), (A15), and (A18)),
6. Mean times spent in the perennial production stages (DEL in Equation (L1)).

Nearly all of the technological coefficients remain constant throughout a simulation run. A notable exception is commodity yields. Learning curves and supply responses for yields are discussed in detail above in component AMPPAP.

Initial Conditions11/

Initial conditions (1953) of variables whose values change during the course of a run must be reset at the start of each run. Some of these include:

1. Land usage (TLPER in Equation (L1) and TLBSH in Equation (L3)),
2. Perennial substream proportions (PSPER in Equation (L2)),
3. Commodity prices and price averages (all of component PG),
4. Traditional and modern processing proportions (PRT and PRM in Equations (A12)-(A21)),
5. Subsistence levels (SUBLEV in Equation (A3)),

10/ *See Appendix V.C for tabulated values of selected technological coefficients used in the Southern model.*

11/ *See Appendix V.C for tabulated values of selected initial conditions used in the Southern model.*

6. Market price of food ($PRFD_2$ in Equation (C9) and $PPRCM_5$ in Equation (A28)).

A few of these variables present no data problems. For instance, assuming all agricultural processing at time zero (1953) is traditional, we have PRT = 1 and PRM = 0. Others, particularly initial land usages, are more elusive. Initial acreages were estimated from FAO and ministry figures and land surveys. The model is quite sensitive to the initial land usages, as we shall discuss later, so more complete and accurate land surveys would be a profitable venture from the point of view of increasing this model.

It must be stressed that the model can be useful to the policy maker in spite of imprecise parameter estimates. Runs can be made in a Monte Carlo mode (see Chapter IV) where parameter values are drawn from a probability distribution; a range of statistics for each performance criteria can then be generated, which may be more realistic than a "precise" point prediction. More importantly, however, predicting the relative consequences of alternative policy options is usually of more decision-making value than predicting absolute output levels. Therefore, as long as the model preserves the relative order of policy results, even though uncertain parameters vary within some confidence range, the model remains a useful tool in the developmental planning process.

Testing and Validating the Model

For a decision maker to base policy decisions on the experimental results of a model--any model, verbal or mathematical, paper and pencil or computer--he must have some degree of confidence in the validity of that model, i.e., how well it simulates the relevant behavior of the real system or phenomenon it is supposed to represent. There are primarily three ways in which the model discussed here may be validated.

The first is by a sort of knowledgeable intuition. During the building of the model, much reliance for both data and structural and causal relationships was placed on people with a great deal of experience in Nigeria and other developing countries. In addition, secondary sources were used. By studying the simulated behavior of the model, these same people and others like them, may, through their expertise, have an intuitive feel for how well the model represents the real economy. This would be an on-going process, continuing even once the model has been implemented and is in routine use. More concretely, behavior predicted by the model under various policy conditions can be compared with what actually occurs as real time passes under the same conditions; or, alternatively, the model can be compared with historical data from the real world which has not been used in the model-building process. Once the model has been implemented, it may be tuned and updated as an on-going process by making such comparisons.

Time Series Tracking

Before the model is ready to be implemented it must be "tuned" to track one or more time series of past behavior. The tuning may require adjusting the values of certain system parameters or the addition of new mechanisms. In attempting to track a particular time series, dozens of parameters may be likely candidates for adjustment. It takes an understanding of the real system and a deep familiarity with the simulation model to focus on the one or two parameters which would be meaningful to adjust, or to know where a structural relation must be added to the model to make its behavior conform more closely to experienced behavior.

Four time series (1953-65) were used to tune the Southern model: exports of cocoa, palm oil and rubber, and food pri s. The measure of goodness-of-fit used (one of many possible) is:

$$TSS = \sum_{i=1}^{4} SS_i$$

<u>where</u>:

$$SS_i = \sum_{j=1}^{13} \left(\frac{Y_{ij} - \hat{Y}_{ij}}{\bar{Y}_i}\right)^2 \qquad , i = 1,2,3,4$$

$$\bar{Y}_i = \frac{1}{13} \sum_{j=1}^{13} Y_{ij} \qquad , i = 1,2,3,4$$

<u>and where</u>:

SS_i = the sum-of-squared normalized deviations for Series i

TSS = the total sum-of-squared deviations

Y_{ij} = the real data value at year j of Series i

$\hat{Y}_{ij}$ = the simulated data value at year j of Series i

$\bar{Y}_j$ = the mean of the real Series i

The squared deviations are normalized so each of the four sums has equal weight when all are added together. The closer to zero, the better the fit. If the model generated nothing but zeros, i.e., $\hat{Y}_{ij} = 0$ for all i and j, we would have::

$$SS_i = 13 + \frac{12S_i^2}{\bar{Y}_i^2} \qquad , i = 1,2,3,4$$

where:

S_i^2 = the sample variance of Series i.

Thus, TSS would be somewhat greater than 52.

During the 13 years of time-series tracking, the model uses the actual F.O.B. and producer prices received by Nigeria and set by the marketing boards in those years (1953-65). These values are used in place of Equations (P1), (P5) and (P6).

Table 5.3 displays the four time series resulting after the initial coarse tuning. Data values generating this fit were used in the policy runs discussed later in this chapter and in Chapter IX.

TABLE 5.3
Time Series Tracking.

YEAR	COCOA EXPORTS (thous. lbs./yr.) DATA	COCOA EXPORTS SIMULATED	PALM OIL EXPORTS (thous. lbs./yr.) DATA	PALM OIL EXPORTS SIMULATED	RUBBER EXPORTS (thous. lbs./yr.) DATA	RUBBER EXPORTS SIMULATED	FOOD PRICE (£/lb.) DATA	FOOD PRICE SIMULATED
1953	234,463.	233,331.	451,013.	392,181.	47,622.0	47,672.9	.0100000	.0101527
1954	220,355.	244,870.	467,000.	390,317.	46,816.0	50,057.8	.0108300	.0102980
1955	198,045.	256,147.	408,000.	383,731.	68,051.0	62,975.3	.0120800	.0104089
1956	262,378.	265,591.	414,926.	381,035.	85,454.0	67,284.6	.0141700	.0104872
1957	303,072.	281,235.	372,288.	377,809.	89,582.0	75,927.4	.0120800	.0106316
1958	196,331.	300,098.	381,938.	372,716.	92,301.0	86,161.7	.00917000	.0107879
1959	319,872.	324,046.	366,670.	367,798.	119,558.	102,557.	.0104200	.0111070
1960	352,074.	350,473.	410,726.	361,965.	128,193.	121,211.	.0125000	.0112826
1961	411,964.	373,238.	368,686.	355,754.	123,574.	118,132.	.0133300	.0113934
1962	436,020.	405,767.	265,816.	342,013.	133,580.	128,453.	.0137500	.0115884
1963	392,000.	437,175.	282,240.	333,807.	141,431.	141,745.	.0108300	.0117895
1964	441,280.	467,472.	300,160.	327,822.	161,435.	147,752.	.0112500	.0120063
1965	571,200.	480,657.	336,000.	315,602.	152,038.	160,228.	.0137500	.0122073
SS	.256656		.169741		.108401		.253351	

TSS = .788149

Adjustments made in the tuning process included data values and structural relationships. For example, the model was not simulating the rapid increase in either cocoa or rubber exports. In the case of cocoa, it was necessary to incorporate the diffusion of improved practices (defined in Table 5.2), a process which actually did take place in the 1950's and 1960's in Nigeria. This was accomplished by setting, as an initial condition, 5 percent of the traditional cocoa in the improved substream ($PSPER_{1k}(0)$ = 0.95 for all k, in Equation (L2)) and adjusting the diffusion parameter ($CIUDT_{11}$ in Equation (L8) and Table 5.C.1.c) so that by the end of the tracking period (1965), about 95 percent of the traditional cocoa was improved. Similarly, simulated smallholder rubber production was not generating the exports actually experienced. FAO estimates of acreages and outputs of rubber estates (FAO, 1966) indicate that this made up most of the discrepancy. Thus, the rubber estates factor discussed earlier (in the AMPPAP component description and Equation (A24)) was added to the model. Further agreement with actual rubber exports was obtained by increasing the initial (1953) estimated rubber acreage ($TLPER_{5k}(0)$ for all k) from a total of 350,000 acres to 380,000 acres.

General Validation

Tuning the model to track four time series is not nearly enough. The Southern model, merged with the other major components of the total Nigerian model, was further refined in a process of intuitive, theoretical and empirical consistency analyses.

For example:

1. The national accounts had to balance,

2. The agricultural and nonagricultural per capita consumption of food had to be in the "right" neighborhood according to intuitive judgments and empirical evidence about nutritional levels in the Nigerian population,

3. The market price of food had to be in a reasonable range, neither too large nor too small,

4. GDP and value-added growth rates in the agricultural and nonagricultural sectors had to approximate expectations based on economic theory and empirical and simulated conditions in Nigeria,

5. Land-use decisions had to respond "properly" to changing profitabilities of alternatives.

This process of general validation is very judgmental and often intuitive. In spite of this, or even because of it, the process must be an on-going part of the model's application if the model is to remain useful and credible.

Sensitivity Analysis

Sensitivity tests identify those parameters to which the model is most sensitive, i.e., for which the model's behavior responds the most as parameter values are changed. Such information is important in the tuning and validation process, useful to the policy maker and crucial in identifying the most profitable areas to invest scarce data collection resources. These three applications of sensitivity analysis, illustrated in Table 5.4, are not mutually exclusive but rather overlap and reinforce each other.

Table 5.4 displays selected results of changes in the parameters listed in the first column compared with a standard base run. While the parameters tested are grouped by application (model validation--Runs 2-8; data collection--Runs 9-18; policy implication--Runs 19-25), some of them certainly apply to more than one group. For example, there could be a policy aimed at increasing the proportions of acres harvested (Runs 9 and 10), i.e., harvesting to capacity. Also, the palm-processing loss factor (Run 19, an indication of extraction rates) was used in tuning the model to conform with palm oil exports.

This last point has an interesting policy implication. While the goodness-of-fit of the palm oil tracking (Table 5.3) indicates a degree of confidence in the value of the palm-processing loss factor used, the results of Run 19 suggest there are significant benefits to be gained from policies directed at increasing oil and kernel extraction rates.

Parameters affecting food production[12/] are also quite sensitive and, hence, have implications for data collection activities and for policy making. For instance, Runs 11 and 12 indicate that while cocoa marketing costs have relatively little impact, doubling the marketing costs of food slightly depresses per capita income, and there is a 17 percent rise in food prices by the end of the 32-year run. Increasing food yields in one crop sector (Runs 24 and 25) tend to decrease nominal incomes in the

12/ *Runs 3, 4, 7, 12, 17, 18, 24, 25.*

TABLE 5.4
Selected Results of Southern Model Sensitivity Tests.

Performance Criteria / Run Definitions[a]	Per capita disposable income in the Cocoa Sector at year 32 PCDINC$_1$ (₦/person-yr)	Per capita disposable income in the Palm Sector at year 32 PCDINC$_2$ (₦/person-yr)	Per capita disposable income in the Rubber-Palm Sector at year 32 PCDINC$_3$ (₦/person-yr)	Per capita disposable income in the Annuals Sector at year 32 PCDINC$_4$ (₦/person-yr)	Market price of food in the South at year 32 PMFD (₦/lb)	Foreign exchange from agricultural exports accumulated over 32 years AFORXS (million ₦)	Agricultural value added accumulated over 32 years ATVAS (million ₦)	Total sum-of-squared deviations from four data series over 13 years TSS
1. Standard run	27.93	24.61	35.34	22.79	.01790	2,952.	13,210.	.7953
2. Bush to traditional cocoa profitability discount rate (+25%)	27.37	25.04	36.32	22.22	.01758	2,837.	13,080.	.8166
3. Bush to food profitability response rate (+100%)	25.16	22.70	34.19	20.70	.01440	2,943.	12,310.	.8669
4. Bush to food (Annuals Sector) diffusion parameter (+100%)	23.07	21.65	33.18	27.61	.01508	2,954.	12,640.	.8177
5. Improvement of traditional cocoa diffusion parameter (+100%)	27.93	24.64	35.36	22.82	.01791	2,998.	13,260.	.9394
6. Per capita consumption of palm oil in the South (+8%)	28.81	27.64	39.38	23.19	.01785	2,908.	13,300.	1.070
7. Short run supply (harvest) elasticity of food (-33.3%)	28.51	25.16	35.99	23.99	.01888	2,948.	13,560.	.7633
8. Short run supply (harvest) elasticity of oil palm (+133.3%)	27.56	23.90	34.39	22.69	.01790	2,961.	13,210.	.7943
9. Proportion of palm acres (Palm Sector) harvested (-16.7%)	30.12	28.35	45.48	23.77	.01778	2,818.	13,200.	2.255
10. Proportion of rubber acres harvested (+40%)	27.94	24.62	40.06	22.80	.01789	3,110.	13,340.	2.367
11. Cocoa marketing cost (proportion of price) (+100%)	26.71	24.39	35.11	22.59	.01795	2,932.	13,270.	.7953
12. Food marketing cost (proportion of price) (+100%)	27.61	24.26	34.63	21.91	.02099	2,958.	13,890.	.7553
13. Initial bush land in the Palm Sector (+20%)	26.88	24.14	32.91	21.79	.01756	2,974.	13,130.	.8078
14. Initial traditional cocoa land (+20%)	29.44	24.90	35.64	23.04	.01802	3,290.	13,540.	1.382
15. Initial traditional palm land (Palm Sector) (-25%)	30.35	29.30	47.45	23.67	.01761	2,773.	13,160.	3.744
16. Palm products marketing loss factor (-10.5%)	29.69	30.23	42.94	23.65	.01779	2,821.	13,560.	2.234
17. Food marketing loss factor (-15.5%)	32.64	27.42	35.64	28.12	.01899	2,933.	13,410.	.7710
18. Food produced and withheld for planting materials (+25%)	28.49	25.05	35.57	23.35	.01870	2,955.	13,450.	.7764
19. Palm processing loss factor (+50%)	27.30	25.68	36.48	23.61	.01863	3,735.	14,350.	26.12
20. Rubber processing loss factor (-5%)	27.90	24.56	34.74	22.76	.01788	2,930.	13,190.	.9046
21. Yield of traditional palm (Palm Sector) (+33.3%)	27.06	23.68	30.03	22.55	.01807	3,305.	13,640.	4.928
22. Yield of traditional rubber (+25%)	28.01	24.72	38.25	22.86	.01793	3,057.	13,310.	1.385
23. Yield of traditional palm (Rubber Sector) (+33.3%)	27.24	22.06	36.79	22.49	.01795	3,056.	13,310.	1.124
24. Yield of traditional food (Cocoa Sector) (+14.5%)	29.29	23.23	34.40	19.04	.01643	2,946.	12,750.	.8552
25. Yield of traditional food (Annuals Sector) (+14.5%)	25.30	23.03	34.11	25.52	.01645	2,954.	12,840.	.8137

a/ The per cent change from the standard run is given in parentheses and reflects the range of uncertainty in the parameter value.

other sectors; however, real incomes tend to rise since food prices drop even more, about 10 percent.

One interesting observation can be made concerning palm oil. The parameters specific to oil palm products (and palm oil in particular), including those illustrated in Table 5.4[13/] and others, are particularly sensitive, usually in a mixed or negative way.[14/] That is, a change which increases palm oil production tends to decrease agricultural incomes and value added and raise the level of agricultural subsistence, i.e., lessen reliance of the agricultural population on the food market, while increasing foreign exchange earnings and marketing board revenues. This is due to the role of palm oil in domestic consumption. By the end of the 32-year simulation run (1985), Nigeria is no longer exporting palm oil, and domestic demand exceeds supply. When this is the case, the domestic price of palm oil is determined endogenously (Equation (P4)), rather than by the world price and marketing board policies, which will be lower.

This analysis is a good example of how the model, at its present stage of development and coarse validation, must be interpreted with caution. In this case, perhaps behavior which the current model does not allow would take place and result in increasing the supply of palm oil such that the domestic price would remain comparable to the world price. For example, food land might be planted in traditional palm; or palm might become competitive with cocoa in Sector 1. Nor does the model now treat the possibility of meeting excess demands with imports of palm oil or with the substitution of groundnut oil or cottonseed oil. Further research would be necessary to determine which, if any, of these or other possibilities are the most realistic to use in subsequently modifying the model. The first set of parameters tested (Runs 2-8) suggests that some behavioral system parameters are quite sensitive and others are not. Although new types of field surveys might help to improve the estimated values of some of these parameters, they may not be necessary, for reasons already discussed at the end of the section on data usage.

Policy Experiments

Two sets of policy experiments were performed in a series of 24 runs with the Southern model.[15/] The first set performed a sensitivity analysis on the modernization campaign policies; the second set compared the results of running 3 of the 17 possible campaigns (defined in Table 5.2) individually, and in various combinations with each other and with marketing board policies. These experiments represent a small sample of the many possible trials which could be made, but they illustrate one type of analysis that might be made on the results of a simulation model which does not seek to optimize some objective function.

Sensitivity of Campaign Policies

The model administers production campaign policies through the modernization executive component described in Chapter IV. Briefly, a time profile of budget expenditures is specified for each campaign (Figure 4.10). Out of this budget come

13/ *Runs 6, 8, 9, 15, 16, 19, 21, 23.*

14/ *One notable exception is Run 19 discussed above.*

15/ *See Chapter IX for a discussion of policy runs on the total Nigerian model.*

expenditures for input price and cash grant subsidies, overhead expenses and salaries for promotional and technical assistance extension agents. The maximum annual budget expenditure, its time profile and the subsidies may be specified by the policy maker. These policies were tested to determine the sensitivity of campaign results to policy changes.

The policies tested (on a campaign to plant modern cocoa on bush or food land) were:

1. RMAXRG = the maximum annual campaign budget,
2. PSUB = the price subsidy on chemical and biological inputs,
3. CSHSUB = the annual cash subsidy per acre,
4. TCSHSU = the number of years the cash subsidy is given.

The campaign began in year 12 (1964), and ran for 40 years (until 1993).

The results (Table 5.5) indicate that while none of these policy parameters is very sensitive, RMAXRG and TCSHSU have more effect than the others. The former (the overall budget level) is self-evident; the latter result is probably due to cash subsidy expenditures competing for resources which might otherwise be used to increase the promotional extension effort. Table 5.5 shows the effects on the three performance criteria most affected by the policy changes indicated in the first column.

Modernization Programs

Fourteen 40-year runs were made with three modernization programs individually and in combination: cocoa new planting, rubber replanting and improvement of traditional palm in the Palm Sector.16/ These three were chosen as illustrative examples because they affect different commodities, different ecological zones and different approaches to perennial modernization. Table 5.6 shows the impact of each experiment on 10 performance criteria.

A couple of observations can be made regarding the rubber and palm programs. In Run 5 (rubber replanting), income in the Rubber Sector is only slightly higher than in the standard run, whereas one might expect a more significant increase. Foreign exchange earnings and value added have actually decreased from Run 1. These results are due to the fact that a large portion of the older, more mature traditional rubber has been replaced with modern rubber, much of which (in year 40, or 1993) is still in the gestation and rising-yield production stages. As time goes on, and these trees reach full production, the program can be expected to come to fruition.

Second, the runs involving palm improvement (Runs 6-9) confirm the observation made above in connection with the sensitivity tests. Increasing palm production has, in the long run, a depressing effect on incomes, although foreign exchange and marketing board surpluses are higher. However, other factors (discussed above), which this model does not at present consider, may come into play to meet the excess domestic demand for palm oil which, here, sends the price up.

16/ *See Table 5.2 for definitions of these programs.*

TABLE 5.5
Sensitivity of Campaign Policies.

Performance Criteria / Run Definition[a/]	Total foreign exchange accumulated over 40 years AFORXS (million ₺)	Disposable income in the Cocoa Sector at year 40 $SAGDI_1$ (million ₺)	Cocoa marketing board revenues at year 40 $REVMBS_1$ (million ₺)
1. Standard Run[b/]	8,599.	348.4	84.31
2. Maximum annual campaign budget (RMAXRG) increased 50%	8,663.	348.5	84.53
3. Budget decreased 50%	8,382.	348.4	83.57
4. Input price subsidy (PSUB) increased 50%	8,599.	348.6	84.31
5. Price subsidy decreased 50%	8,598.	348.2	84.30
6. Annual cash grant subsidy (CSHSUB) increased 50%	8,599.	348.5	84.30
7. Cash subsidy decreased 50%	8,598.	348.3	84.30
8. Cash subsidy time period (TCSHSU) increased 100%	8,595.	348.3	84.26
9. Cash subsidy time decreased 67%	8,598.	348.4	84.30
10. Cash subsidy increased 200% and time period decreased 67%	8,598.	348.6	84.30
11. Cash subsidy decreased 50% and time period increased 100%	8,596:	348.3	84.27

a/ Each run simulates a campaign to plant modern cocoa on bush or food land, but with different budget and subsidy policies.

b/ Base values of the policies are:
RMAXRG = 2.5 million ₺/year
PSUB = .5 (proportion of price)
CSHSUB = 5₺/acre-year
TCSHSU = 3 years

TABLE 5.6
Perennial Modernization and Marketing Board Policy Experiments.

Performance Criteria / Run Definitions	Agricultural disposable income in the Cocoa Sector at year 40 SAGDI$_1$ (million ħ)	Agricultural disposable income in the Palm Sector at year 40 SAGDI$_2$ (million ħ)	Agricultural disposable income in the Rubber-Palm Sector at year 40 SAGDI$_3$ (million ħ)	Agricultural disposable income in the Food-Cash Annual Sector at year 40 SAGDI$_4$ (million ħ)	Accumulated foreign exchange earnings from Southern agricultural exports over 40 years AFORXS (million ħ)	Accumulated agricultural value added over 40 years ATVAS (million ħ)	Marketing board surplus from Southern export crops at year 40 TMBREV (million ħ)	Market price of food in the South at year 40 PRFD (ħ/lb)	Southern agricultural per capita annual calorie consumption at year 40 PCFAC (million calories/person)	Southern nonagricultural per capita annual calorie consumption at year 40 PCFNAC (million calories/person)
1 Standard run[a]	291.7	476.3	141.1	193.0	4,252	21,520	27.64	.02145	686 0	628.3
2 All marketing board surplus proportions = 0	309.6	471.7	139.8	194.7	4,100	21,310	001045	.02142	686 0	628 6
3 Cocoa new planting[b]	348 4	823.3	227.6	283.8	8,599	26,840	86.73	02593	684.8	591.5
4 Cocoa new planting with cocoa marketing board surplus proportion = 0	424 8	827.9	228.9	284.4	8,635	26,780	2 417	.02575	684.4	592.8
5. Rubber replanting[c]	289.1	475.1	143.1	190.4	4,238	21,480	27.64	.02128	686.0	630.0
6 Palm improvement[d] (Palm Sector)	267 7	356.0	94.08	185.6	4,264	21,120	27 88	.02148	689.1	628 0
7 Palm improvement (Palm Sector) with palm oil marketing board surplus proportion = 0	267.1	347.3	92.26	185.1	4,259	20,970	27.88	.02149	689.2	627.9
8 Palm improvement (Palm Sector) with palm kernel marketing board surplus proportion = 0	268.0	359.1	94.74	186.1	4,268	21,110	25.13	.02150	689.1	627 8
9. Palm improvement (Palm Sector) with both palm marketing board surplus proportions = 0	267.4	350.2	92.90	185.6	4,264	20,960	25.14	.02151	689.2	627.7
10 Cocoa new planting and rubber replanting	346.3	820.3	231.?	279.3	8,585	26,800	86 72	.02567	684.9	593.6
11 Cocoa new planting and palm improvement (Palm Sector)	342.2	563.7	134.7	279.5	8,610	26.180	87.00	02630	687.1	588.3
12. Rubber replanting and palm improvement (Palm Sector)	265.1	354.6	96.18	183.0	4,249	21,080	27.88	.02130	689.1	629.8
13. Cocoa new planting, rubber replanting and palm improvement (Palm Sector)	340 4	568.8	140.0	273.4	8,469	26,020	86.54	.02589	687.1	591.5
14. Run 13 with all marketing board surplus proportions = C	416.7	560.2	138.3	274.8	8,509	25,780	.002882	.02580	686.8	592.1

a/ No modernization; all marketing board surplus proportions = .2.
b/ Modern cocoa planted on bush or food land.
c/ Modern rubber replacing traditional rubber.
d/ Modern methods on traditional palm.

The policy runs may be analyzed by a policy maker in a number of ways. For instance, suppose we are interested in increasing agricultural sector disposable income; this is income (Equation (C9)), net of operating expenses, debt service and interest, taxes and food expenditures, available for consumption and investment. From this point of view, Runs 4 and 7 appear (Table 5.6) to generate the best and the poorest results, respectively. Table 5.7 shows the percentage difference between the standard run (Run 1) and Runs 4 and 7 for each of the 10 performance criteria. The percentage differences in the runs yielding the highest and lowest values of these criteria are also given where these runs are other than Runs 4 or 7.

These runs indicate that policies generating the highest levels of disposable income also result in high foreign exchange earnings but very low marketing board surpluses. On the other hand, the run resulting in the highest marketing board surpluses (Run 11), also generated the highest food prices and lowest nonagricultural sector food consumption. A middle ground might be reached as indicated by Run 3 (Table 5.6). It would be up to the policy maker to decide which results are "best" or "desired." Such a decision would, of course, require more extensive analysis and experimentation with these and others of the 17 modernization campaign programs described in Table 5.2.

These results are from a very coarse model. A good deal of refinement and validation must precede actual implementation of the model. Nevertheless, these experiments illustrate what can be done and probably provide a fairly accurate picture of the <u>relative</u> consequences of the various policies tested, even if the <u>absolute</u> levels may be less certain.

Further Work

The model is still preliminary, and much validation and refinement are necessary before it is ready to be institutionalized in the development planning process. Extensive field survey work will sharpen the enormous data requirements of the model and confirm the structural assumptions. The data include: (1) technological coefficients, e.g., yields, labor and capital requirements, etc., relevant to actual smallholder operations; (2) behavioral parameters, e.g., the discount rates and profitability response parameters of the land allocation mechanism discussed earlier, and (3) initial conditions such as acreages in the various crops and commodity prices. In some cases, it would be useful to introduce probability distributions for uncertain parameters which are known to be significant in their effect on model behavior. The model would then be run in a Monte Carlo mode to compute statistics for important output variables.

Some of the structural assumptions to be confirmed are: (1) whether labor is a constraint to expanded agricultural production (it is currently assumed not to be a constraint); (2) whether some of the land-use alternatives not considered in the model (Table 5.1) should be added to the model, and (3) whether the capital constraint to increased production, as modeled, adequately represents the actual situation. Indeed, it may be that this phenomenon cannot be fully incorporated in the model until the whole question of the distribution of income in the agricultural sector is modeled explicitly into the land allocation decisions and production behavior.

In addition to field surveys, reprogramming will be needed before the model can implemented. A user-oriented package of generalized components is necessary to: (1) provide a simple procedure for defining and conducting policy experiments; (2) display simulated results in easily readable form, and (3) allow components to be easily removed and reassembled as needed for application in different countries.

TABLE 5.7

Highest and Lowest Values of Performance Criteria: Runs Generating Highest Disposable Incomes

Performance Criteria / Definitions[a/]	Agricultural disposable income in the Cocoa Sector at year 40 SAGDI$_1$	Agricultural disposable income in the Palm Sector at year 40 SAGDI$_2$	Agricultural disposable income in the Rubber-Palm Sector at year 40 SAGDI$_3$	Agricultural disposable income in the Food-Cash Annual Sector at year 40 SAGDI$_4$	Accumulated foreign exchange earnings from Southern agricultural exports over 40 years AFORXS	Accumulated agricultural value added over 40 years ATVAS	Marketing board surplus from Southern export crops at year 40 TMBREV	Market price of food in the South at year 40 PRFD	Southern agricultural per capita annual calorie consumption at year 40 PCFAG	Southern nonagricultural per capita annual calorie consumption at year 40 PCFNAG
4. Cocoa new planting with cocoa marketing board surplus proportion = 0	+45.7%	+73.8%	+62.1%	+47.3%	+103.%	+24.5%	-91.4%	+20.0%	-.233%	-5.66%
7. Palm improvement (Palm Sector) with palm oil marketing board surplus proportion = 0	-8.45%	-27.1%	-34.5%	-4.09%	+.164%	-2.56%	+.868%	+.186%	+.467%	-.333%
Run with highest value (in parenthesis)	--	--	+63.8%	--	--	+24.7%	+214.%	+22.6%	--	+.271%
Run with lowest value (in parenthesis)	-9.15%	--	--	-5.18%	-.329%	-2.6%	-99.99%	-.758%	--	-6.38%

a/ The last two rows are used if the highest or lowest value occurred in a run other than Runs 4 or 7. Definitions for such runs are in Table 5.6. Figures are percent differences from the standard run (Run 1).

CHAPTER V : APPENDIX A

The Food Composite

WE HAVE DEFINED "food" as a composite of the staples produced and consumed in the South. The four staples making up the food composite are yam, maize, cassava and cocoyam. A weighted average of these is used as the definition of food. The weights used are as follows:

--yam = 0.315

--maize = 0.278

--cassava = 0.310

--cocoyam = 0.097

These weights were derived from acres in production as reported in the Rural Economic Survey, Farm Survey, 1964-65, Federal Office of Statistics, Lagos, Nigeria.

The weights are used with the four staples to determine the food yield, labor inputs, biological inputs, chemical inputs and the calorie yield of food.

Table 5.A.1 gives the values of these variables used in the Southern model. The equation numbers in parentheses refer to the equations in Appendix V.B.

TABLE 5.A.1
Food Composite Production Co-efficients.

Variable (Eqn. No.)	Definition	Composite Value
YF1 (A4, A5)	traditional food yields	6,550 lbs./acre-year
YF2 (A4, A5)	modern food yields	11,900 lbs./acre-year
FDLAB1 (A25)	traditional food maintenance labor	78 man-days/acre-year
FDLAB2 (A25)	modern food maintenance labor	86 man-days/acre-year
FDLABY (A25)	food harvesting labor	.00385 man-days/lb.
FDBIO (A26)	food biological inputs	827 lbs./acre-year
FDCH1 (A26)	traditional food chemical inputs	0 lbs./acre-year
FDCH2 (A26)	modern food chemical inputs	200 lbs./acre-year
CALY (A7)	calorie yield of food	827 calories/lb.

Sources: [Phillips, 1964], [Gusten, 1968], [Thodey, 1969], [Okurume, 1969], [FAO, 1966].

CHAPTER V : APPENDIX B

Component Equations

THIS APPENDIX PRESENTS the major equations of the model components. Verbal descriptions and explanations of the basic structural assumptions, discussed in detail in the body of the chapter, are kept to a minimum. Thus, the reader may find it necessary, for an understanding of the model, to read this appendix in conjunction with the main chapter.

Component LAMDAP

Land Uses

A demographic cohort model is used for the perennial commodities as they age through time and various production stages. Each production cohort is modeled as a third-order distributed lag (Llewellyn, 1965). This simulates, in effect, a probability density for the time spent in a production stage. A parameter k (k = 3 in Equation (L1)), determines the shape of the probability density (Figure 5.B.1). If k = 1, an exponential distribution is assumed, and, as $k \to \infty$, the distribution (a gamma distribution) approaches a normal distribution. The lag is called a k^{th}-order delay and is equivalent to k first-order (exponential) delays in series, where the output of one stage is the input to the next. Whatever the value of k, the mean lag time for the cohort (the mean of the distribution) is given by the parameter DEL.

The aging rates and level of each cohort are updated each time period by Equation (L1).

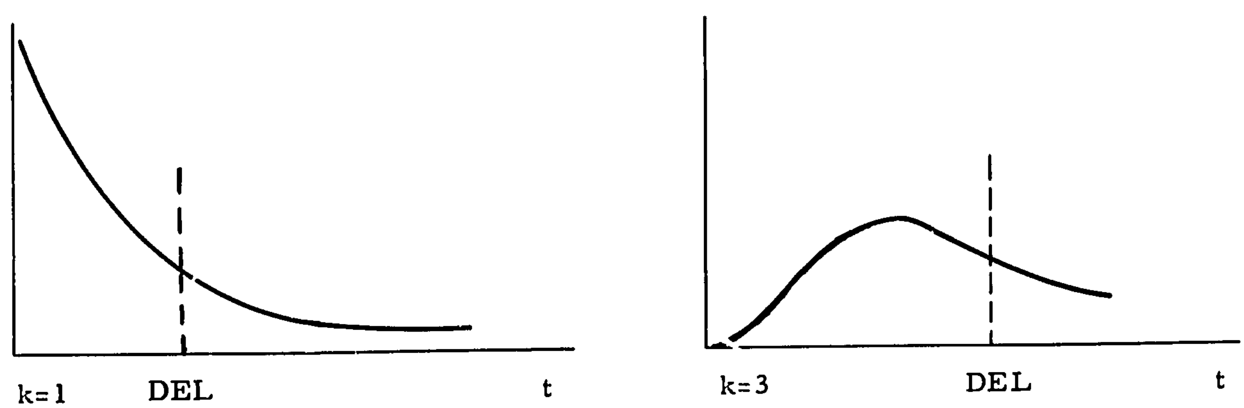


Figure 5.B.1. The gamma distribution.

(L1) $COHDR_{ijn}(t) = COHDR_{ijn}(t-DT) + \frac{DT}{(DEL_{jn}/3)}*[COHDR_{(i-1)jn}(t) - COHDR_{ijn}(t-DT)],$

$i = 1,2,3$

$$TLPER_{jn}(t) = \frac{DEL_{jn}}{3}*\sum_{i=1}^{3} COHDR_{ijn}(t)$$

where:

$COHDR_i$ = the three delay rates (i = 1,2,3) of a third-order cohort delay--thousands of acres/year

DEL = the mean lag time of a production cohort--years

DT = the time period of a simulation cycle--years

TLPER = the amount of land in a cohort--thousands of acres

j = indexes the cohorts--j = 1-4

n = indexes the perennial population streams--n = 1-8.

When i = 1, $COHDR_{0jn}$ is the rate land enters the cohort. If j = 1, (the first cohort, gestation stage, of a perennial population stream), $COHDR_{0jn}$ is the planting rate determined by the land-use decisions. Otherwise, $COHDR_{0jn}$ is the output rate of the previous cohort, where the output rate of cohort (j-1) is $COHDR_{3(j-1)n}$.

The two substreams of each perennial population stream are treated as proportions. Specifically, the model keeps track of the proportion of land in the first substream via Equation (L2).

(L2) $PSPER_{jn}(t) = [RINR_{jn}(t)*DT*PSPER_{(j-1)n}(t-DT) + PSPER_{jn}(t-DT)* \{TLPER_{jn}(t-DT) - (ROUTR_{jn}(t) + TREXIT_{jn}(t)*PTOUT)*DT\} - TRMOD_{jn}(t)*DT]/TLPER_{jn}(t)$

where:

PSPER = proportion of total land which is in the first substream

RINR = the rate land enters the cohort--thousands of acres/year

ROUTR = the rate land leaves the cohort to the next older cohort--thousands of acres/year

TREXIT = the rate land leaves the cohort to alternative uses--thousands of acres/year

PTOUT = a parameter determining how much of the land leaving a perennial stream comes from the first substream (PTOUT = 1, means proportionately from each substream)--dimensionless

TRMOD = the rate land moves from the first to the second substream (i.e., improvement of traditional perennials)--thousands of acres/year

j = indexes the cohorts--j = 1-5

n = indexes the perennial streams--n = 1-8.

For j = 1 (the first cohort), RINR is the planting rate and $PSPER_{0n}$ is the proportion planted into the first substream. Otherwise, RINR is the ROUTR of the previous cohort (= $COHDR_{3(j-1)n}$ discussed under Equation (L1)).

Food land is updated by Equation (L3). Cash annual (tobacco) land and bush land are updated by similar equations.

(L3) $TLFD_k(t) = TLFD_k(t-DT) + [RINF_k(t) - ROUTF_k(t)]*DT$

where:

TLFD = total food land--thousands of acres

RINF = rate land from other uses is planted in food--thousands of acres/year

ROUTF = rate food land is transferred to other uses--thousands of acres/year

k = indexes the crop sectors--k = 1-4.

The proportion of food land in traditional production (the first substream) is determined by an equation similar to Equation (L2).

Decisions

Land transition decisions are based on the profitability differentials of alternatives relative to present uses as calculated in Equation (L4).

(L4) $$PDR_{ij}(t) = \frac{(AVMAX_i(t) - AVMAX_j(t))}{|AVMAX_j(t)|} \quad i = 1, \ldots, n_j$$

where:

PDR = the relative profitability differential--dimensionless

AVMAX = the maximum annual average of returns over the planning horizon (see Equation (L5))--thousands £/thousand acre-years

i = indexes the alternatives to a present use--i = $1\text{-}n_j$

n_j = the number of alternatives open to a present use (see Table 5.1)

j = indexes the present uses of a crop sector.

The profitability of a land use, AVMAX, is computed by Equation (L5).

(L5) $$AVMAX(t) = \max_{k \in [1,2,\ldots,n]} \frac{1}{k} \sum_{i=1}^{k} \frac{(TR_i(t) - TC_i(t))}{(1 + DR)^i}$$

where:

AVMAX = as defined above

n = the meaningful planning horizon (see Table 5.1)--years

TR = total revenue--thousands £/thousand acre-years

TC = total cost--thousands £/thousand acre-years

DR = the relevant discount rate

k = an integral number of years

i = indexes k of the n years of the planning horizon--i = 1-k.

Total revenue and total cost are computed simply as:

(L6) $$TR_i(t) = PT_i(t)*Y_i(t) + FNCE_i$$

$$TC_i(t) = PL*XL_i + PBC*XBC_i + PXE_i + PXP_i(t)$$

where:

PT = the expected producer price--thousands £/thousand pounds

Y = the yield--thousands pounds/thousand acre-years

FNCE = cash subsidy grant--thousands £/thousand acre-years

PL = agricultural wage rate--thousands £/thousand man-units

XL = labor input requirement--thousands of man-units/thousand acre-years

PCB = the composite price for chemical and biological inputs--thousands £/thousand pounds

XBC = the composite chemical and biological input requirement--thousands pounds/thousand acre-years

PXE = equipment costs (replacement investment = depreciation)--thousands £/thousand acre-years

PXP = processing costs when producers do their own processing--thousands £/thousand acre-years.

The producer price projected over the planning horizon has a trend factor applied to it at every fifth year of the profitability series.

(L7) $PT_i(t) = PY(t)*(PYR(t))^{[i/5]}$

where:

PY = the five-year exponential average of recent producer prices (= PPAV of Equation (P8))--thousands £/thousand pounds

PYR = the trend factor--the averaged ratio of the current producer price to the previous time period's producer price (= PPAVR of Equation (P8))--dimensionless

[i/5] = the largest integer in the quotient in parentheses.

Information (promotional or diffusion) is necessary to stimulate land transitions. Promotional information units are generated as a policy. Diffusion demonstration units, however, are endogenously determined by Equation (L8).

(L8) $$DINF_{ij}(t) = \frac{TLAVD_{ij}(t)*TLALT_i(t)*CIUD_{ij}}{TLAVD_{ij}(t) + TLALT_i(t)}$$

where:

DINF = diffusion information units--thousands of units (extension agent equivalents)

TLAVD = land in a present use suitable for an alternative by diffusion--thousands of acres

TLALT = land in the alternative use--thousands of acres

CIUD = a coefficient reflecting the information effect of demonstration land units--thousands of units/thousand acres

i = indexes the alternatives

j = indexes the present uses.

The amount of land in a present use which is available to transfer to an alternative may be different for the promotion effect and for the diffusion effect. Also, only bush land other than the fallow necessary to maintain subsistence food yields is available for alternative uses. These concepts are modeled by Equations (L9).

(L9) $FALNEC(t) = SUBFDL(t)*[FFT*PSFD(t) + FFM*(1 - PSFD(t))]$

$$TLPT_b(t) = \max\{[(TLP_b(t) - FALNEC(t)) - DADLV_b(t)], 0.\}$$

$$TLPT_j(t) = TLP_j(t) - DADLV_j(t), \; j \neq b$$

$$TLAVP_{ij}(t) = TLPT_j(t)*CLAVR_{ij}(t)$$

$$TLAVD_{ij}(t) = TLPT_j(t)*CLAVRD_{ij}(t)$$

where:

TLPT = total land in a present use available for transition decisions--thousands of acres

FALNEC = fallow land necessary to maintain subsistence food yields--thousands of acres

SUBFDL = subsistence food land (computed in component AMPPAP Equation (A7))--thousands of acres

FFT(FFM) = proportion of traditional (modern) subsistence food land which must be cycled into fallow to maintain yields

PSFD = proportion of food land that is traditional

TLP = total land in a present use--thousands of acres

DADLV = land in the decision and administrative delay (see below, following Equation (L13))--thousands of acres

TLAVP = land in a present use available for a particular alternative by promotion--thousands of acres

TLAVD = as defined above

CLAVR = proportion of land in a present use available for a particular alternative by promotion

CLAVRD = proportion of land in a present use available for a particular alternative by diffusion

i = indexes the alternatives

j = indexes the present uses (j = b = bush).

Equation (L10) computes the land availability proportions for the perennials. These proportions depend on (1) the overall suitability of the perennial land for each alternative, e.g., ecological factors and, in the case of land to be promoted by production campaign efforts, particular program requirements, and on (2) a parameter which specifies from which perennial production cohorts land may be considered for alternatives. Again, modernization program constraints may indicate certain cohorts to be available by promotion, while behavioral characteristics of the farmers will decide the diffusion responses. The model is simplified to make the decision for an entire perennial population stream and then to apportion the transitions by cohort. However, remember that the transition rates should properly be the results of an economic decision.

$$(L10) \quad CLAVR_{ij}(t) = CLAVT_{ij} * \frac{\sum_{k=1}^{5} TLPER_{kj}(t) * PCTR_{kj}}{\sum_{k=1}^{5} TLPER_{kj}(t)}$$

$$CLAVRD_{ij}(t) = DLAVT_{ij} * \frac{\sum_{k=1}^{5} TLPER_{kj}(t) * DCTR_{kj}}{\sum_{k=1}^{5} TLPER_{kj}(t)}$$

where:

TLPER = defined in Equation (L1)

CLAVT, DLAVT = proportion of land available for promotion and diffusion, respectively, due to soil, climatic, etc. conditions

PCTR, DCTR = parameters indicating perennial cohorts available for transition to alternative uses (= 0 or 1)

i = indexes the alternative uses

j = indexes the perennial present uses

k = indexes the perennial cohorts.

The profitability response function (see Figure 5.5) determines the proportion of an information unit's potential attained as a function of the profitabilities and behavioral parameters. Equations (L11-L13) are given for the promotion response. The equations for the diffusion process are exactly analogous.

(L11) $PR_{ij}(t) = \max\{C3_{ij} * (1 - \exp[-SHAPE_{ij} * (PDR_{ij}(t) - THRLD_{ij})]), 0.\}$

where:

PR = the profitability response to promotion efforts--proportion

C3 = the maximum proportion attainable (see Equation (L12))

exp = the exponential function

SHAPE = the rate of promoted response with respect to the profitability--dimensionless

THRLD = the promotion response threshold--dimensionless

PDR = the relative profitability differential (Equation (L4))--dimensionless

i = indexes the alternatives

j = indexes the present uses.

The maximum response proportion attainable is 1 unless there is a land constraint relative to the number of information units (extension agents). This is determined by Equation (L12).

(L12) $C3_{ij} = \min[\frac{TLAVP_{ij}(t)}{EINF_{ij}(t) * CEFF * DT}, 1.]$

where:

TLAVP = as defined in Equation (L9)

EINF = promotion (extension agents) information units--thousands of units

CEFF = potential efficiency of promotion--thousands of acres/thousand information unit-years

i = indexes the alternatives

j = indexes the present uses.

After determining the profitability response of each information unit, Equation (L13) computes the transition rates due to promotion.

(L13) $TRLDP_{ij}(t) = CEFF*EINF_{ij}(t)*PR_{ij}(t)*CNSIN(t)$

where:

TRLDP = unlagged promoted land transition rate--thousands of acres/year

PR = as defined in Equation (L11)

CNSIN = investment constraint (capital availability--see component CRTMBA, Equation (C12))--proportion

i = indexes the alternatives

j = indexes the present uses.

These transition rates are lagged to account for decision delays and administrative delays involved with enrolling farmers for modernization programs and with the distribution of modern inputs. Land currently in these delays, i.e., already allocated, is assumed unavailable for further allocation. (See Equation (L9) above.)

The capital required to carry out the land transition decision is the sum of the establishment costs.

(L14) $ECAPRT(t) = \sum_{j} \sum_{i} CSHR_{ij}(t)*(DTRLP_{ij}(t) + DTRLD_{ij}(t))*DT$

$CSHR_{ij}(t) = \max(ESTAB_{ij}(t), 0)$

$ESTAB(t) = \{TR_1(t) - [TC_1(t) - PL*XL_1*(1 - PLHIRE(t))]\}/(1 + DR)$

where:

ECAPRT = total capital required for land use transitions in a crop sector--thousands £/year

CSHR = capital required for alternatives--thousands £/thousand acre-years

DTRLP, DTRLD = lagged values of TRLDP and TRLDD (see Equation (L12)), respectively--thousands of acres/year

ESTAB = establishment cost--thousands £/thousand acre-years

TR_1, TC_1 = the values of TR and TC (see Equation (L5)) in the first year of the planning horizon--thousands £/thousand acre-years

PL, XL, DR = as defined in Equations (L5) and (L6)

PLHIRE = proportion of labor hired (computed in component AMPPAP, Equation (A29))

i = indexes the alternatives

j = indexes the present uses.

Notice that only wage labor is considered for the establishment cost, whereas the total value of labor is included as an opportunity cost in TC to compute the expected income stream (Equations (L5) and (L6)).

Demands for modern biological and chemical inputs and capital needs generated by the production campaign efforts are computed in Equation (L15).

(L15) $$ECAPMP_m(t) = \sum_j \sum_i CSHR_{ij}(t)*DTRLP_{ij}(t)*DT$$

$$EBIOMP_m(t) = \sum_j \sum_i EBT_{ij}*DTRLP_{ij}(t)$$

$$ECHEMP_m(t) = \sum_j \sum_i ECHT_{ij}*DTRLP_{ij}(t)$$

<u>where</u>:

ECAPMP = capital demands--thousands £/year

EBIOMP = modern biological input demands--thousands of units/year

ECHEMP = chemical input demands--thousands pounds/year

EBT = biological input requirements for establishment--thousands of units/acre

ECHT = chemical input requirements for establishment--thousands pounds/acre

m = indexes the modernization programs--m = 1-5

i = indexes the modern alternatives

j = indexes the present uses.

Abandonment of perennial land occurs (see Figure 5.6) if continued production becomes too unprofitable.

(L16) $ABANR_j(t) = TLPT_j(t)*max\{PMXAB_j*(1 - exp[-SHPAB_j*(THRAB_j - AVMAX_j(t))], 0\}$

<u>where</u>:

ABANR = abandonment rate--thousands of acres/year

TLPT = defined in Equation (L9)

AVMAX = defined in Equation (L5)

PMXAB = maximum proportion that will be abandoned--proportion/year

SHPAB = abandonment rate--dimensionless

THRAB = abandonment threshold--dimensionless

j = indexes the present uses.

Noneconomic Responses

In addition to the above economic land use decisions, an expansion of cultivated acres occurs with the growth of the population of agricultural decision makers. This expansion is constrained, however, by the profitability of production (must be at least positive) and the availability of bush land.

Equations (L17) to (L21) are given for the first perennial commodity of a crop sector. Similar equations compute this response for the second perennial (Sector 3), for tobacco (Sector 4) and for food.

(L17) $RLTPP_k(t) = A1P_k(t)*(RAGDMX_k(t) + RPSP*RAGDSP_k(t))*EIPA_k(t)*BAPXF_k(t)$

$RAGDMX(t) = max(RAGDMA(t), 0.)$

$RAGDMA_k(t) = RAGDMA_k(t-DT) + \frac{DT}{PEXDEL}*(RAGDCM_2(t)*DLABOR_{k12} - RAGDMA_k(t-DT))$

<u>where</u>:

RLTPP = rate land transfers to the first perennial of a crop sector due to agricultural population growth--thousands of acres/year

A1P = average landholding of the first perennial (Equation (L18))--thousands of acres/thousand decision makers

RAGDMX = the positive rate of change of agricultural decision makers--thousands of decision makers/year

RAGDMA = the lagged rate of change of agricultural decision makers in a crop sector--thousands of decision makers/year

$RAGDCM_2$ = unlagged rate of change of agricultural decision makers in the South (from the population component)--thousands of decision makers/year

RAGDSP = population "pressure" for land, i.e., those constrained out by economic conditions (Equation (L21))--thousands of decision makers

RPSP = the rate at which constrained new decision makers acquire land as the economic constraint eases--proportion/year

EIPA = lagged economic constraint coefficient for the first perennial of a crop sector, $0 \leq \text{EIPA} \leq 1$ (Equation (L19))--dimensionless

BAPXF = bush land availability constraint coefficient, $0 \leq \text{BAPXF} \leq 1$ (Equation (L20))--dimensionless

DLABOR_{k12} = proportion of agricultural labor in the South in each crop sector

PEXDEL = the smoothing lag for the population growth effect on land use--years

k = indexes the crop sectors.

Note that this process is constrained so that a decline in the number of agricultural decision makers will not cause a decline in the number of acres cultivated.

Equation (L18) computes the coefficient representing the average landholdings in the first perennial, A1P.

$$\text{(L18)} \quad \text{A1P}_k(t) = \frac{\text{TLT}_k(t) + \text{TLM}_k(t)}{\text{AGDCM}_{k2}}$$

where:

TLT, TLM = total acres in the first perennial of a crop sector, traditional and modern, respectively--thousands of acres

AGDCM_{k2} = agricultural decision makers in the South in each crop sector (from the population component--thousands of decision makers

k = indexes the crop sectors.

The economic constraint coefficient (EIPA) computed in Equation (L19) requires the profitability of the first perennial to be at least the threshold value for full response (EIPA = 1) and at least zero for any response.

$$\text{(L19)} \quad \text{EIP}_k(t) = \max\left[\min\left(\frac{\text{PDR}_{pb}(t)}{\text{THRLD}_{pb}}, 1\right), 0\right]$$

$$\text{EIPA}_k(t) = \text{EIPA}_k(t\text{-DT}) + \frac{\text{DT}}{\text{PEXDEL}}\left(\text{EIP}_k(t) - \text{EIPA}_k(t\text{-DT})\right)$$

where:

EIP = unsmoothed economic constraint coefficient--dimensionless

PDR = the relative profitability differential (Equation (L4) above)--dimensionless

THRLD = the response threshold--dimensionless

p = indicates perennial alternative

b = indicates bush present use

k = indexes the crop sectors.

The bush land availability constraint coefficient goes to zero as nonfallow bush land decreases. (See Figure 5.B.2.)

$$\text{(L20)}\quad BAPXF_k(t) = \exp[-(CBPXF*(\frac{BAPXO_k}{BAPX_k(t)} - 1))]$$

$$BAPX_k(t) = TLBF_k(t) - TRTOB_k(t)*DT$$

<u>where</u>:

BAPXF = bush land availability constraint factor--dimensionless

exp exponential function

CBPXF = a controlling coefficient

BAPX = bush land available--thousands of acres

BAPXO = initial value of BAPX (at t = 0)

TLBF = nonfallow bush land (= $TLPT_b$ of Equation (L9))--thousands of acres

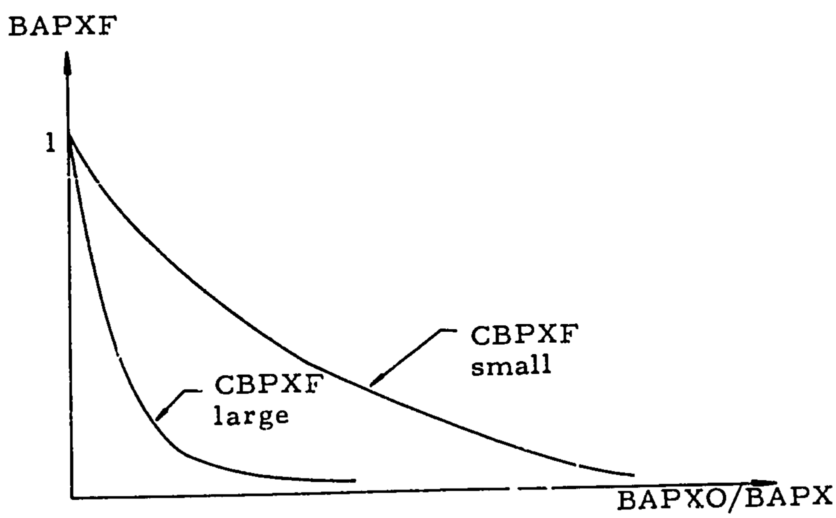


Figure 5.B.2. Land constraint.

TRTOB = total rate of land transferring out of bush to all alternatives due to the economic decisions--thousands of acres/year

k = indexes the crop sectors.

The population "pressure" for land due to economic constraints is computed by Equation (L21).

(L21) $RAGDSP_k(t+DT) = (1 - RPSP*EIPA_k(t))*RAGDSP_k(t) + (1 - EIPA_k(t))*RAGDMX_k(t)*DT$

where:

RAGDSP = as defined in Equation (L17)

EIPA = as defined in Equation (L19)

RAGDMX = as defined in Equation (L17)

RPSP = as defined in Equation (L17).

Component AMPPAP

Subsistence Level

The agricultural subsistence level is a function of a food price stability factor and a food expenditure/cash revenue factor. Equation (A1) calculates the food price stability factor, which is an indication of stability in the food market.

(A1) $$FPRA(i) = \left(\frac{PRFD_2(i) - PRFD_2(i-DT)}{PRFD_2(i-DT)}\right)^2 \quad ; i = t-3, t-3+DT, \ldots, t$$

$$FPSF(t) = \sum_{i=t-3}^{t} FPRA(i)$$

where:

FPRA(i) = the square of the relative change of the food price in the South at time i--dimensionless

$PRFD_2$ = market price of food in the South--thousands £/thousand pounds

FPSF = the food price stability factor--dimensionless

i = indexes three years of time periods incremented by DT.

Note that squaring the relative price change has the effect of including price decreases as well as price increases as a factor of instability in the market.

Equations (A2) compute the food expenditure/cash revenue factor. This factor relates the food price level and the level of demand for food to the net cash revenue from other crops.

$$(A2) \quad EXPFD_k(t) = \left(\frac{DEMRS_k(t)}{CALY*PYCNS}\right)*PRFD_2(t)$$

$$FXCR_k(t) = EXPFD_k(t)/CSHRN_k(t)$$

$$FXCRA_k(t) = FXCRA_k(t-DT + \left(\frac{DT}{FXDEL}\right) (FXCR_k(t) - FXCRA_k(t-DT))$$

where:

CSHRN = total net cash revenue to the agricultural sector in an ecological zone from other than food crops--thousands £/year

EXPFD = value of food consumed by the agricultural sector in an ecological zone--thousands £/year

DEMRS = the calorie requirements of the agricultural sector in an ecological zone--thousands of calories/year

CALY = the calorie content of food--thousands of calories/thousand pounds

PYCNS = the proportion of food which is actually consumed (after spoilage and waste)

FXCR = the food expenditure-cash revenue ratio--dimensionless

FXCRA = the lagged food expenditure-cash revenue ratio of an ecological zone

FXDEL = the length of the smoothing lag--years

k = indexes the perennial crop sectors--k = 1-3.

Finally, then, Equations (A3) recalculate the subsistence level. Figure 5 B.3 illustrates how the mechanism works.

$$(A3) \quad SLRSP_k(t) = SLSHP_k*FPSF(t)^{EFPSF}$$

$$SUBLEV_k(t) = \max\{[1 - (1 - SLMIN_k)*\exp(-SLRSP_k(t-DT)*(FXCRA_k(t-DT) - SLTHR_k))], SLMIN_k\}$$

where:

EFPSF = a parameter to control the effect of the food price stability factor on the subsistence level response rate

SLRSP = subsistence level response rate adjusted by market instability

SLSHP = subsistence level response rate in a perfectly stable food market

SLMIN = the absolute minimum level of subsistence farmers will maintain--proportion of food demand

SLTHR = the value of FXCRA, which is the subsistence level response threshold

SUBLEV = the subsistence level, the proportion of the food requirements of the agricultural population of an ecological zone which is not obtained from the market economy

k = indexes the perennial crop sectors--k = 1-3.

Yields

Perennial and food yields are adjusted by learning curves and price responses. Equation (A4) gives the learning curve increase for, as an example, the first substreams of the perennial population streams.

(A4) $YPER1_{ij}(t) = YPER1_{ij}(t-DT) + (DT/YMDEL1)*(YPER1M_{ij} - YPER1_{ij}(t-DT))$

<u>where</u>:

YPER1 = the yield of the <u>first</u> substream of perennials--thousands pounds/thousand acre-years

YPER1M = the maximum potential yield of perennials in the <u>first</u> substream--thousand pounds/thousand acre-years

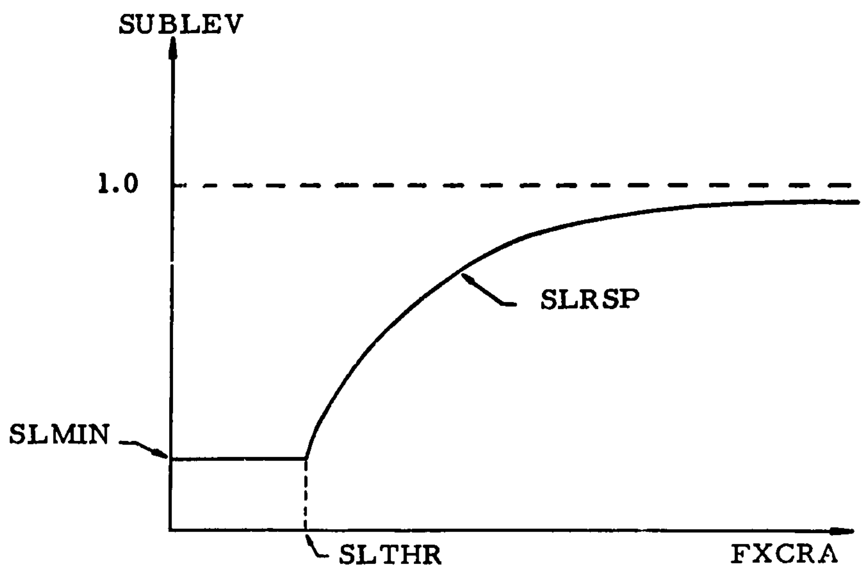


Figure 5.B.3. Subsistence level determination.

YMDEL1 = a lag regulating the rate at which the current yield approaches the potential yield--years

i = indexes the yielding cohorts--i = 1-6

j = indexes the perennial streams--j = 1-8.

Like equations simulate the learning curves for yields of the second perennial substreams, $YPER2_{ij}$, and for yields of the first and second substreams of food, YF1 and YF2.

After the learning curve adjustment has been applied, the yield of each crop is averaged across the substreams. In calculating this average, the yield of each substream is weighted by the land in that substream. This function is performed by Equation (A5). Yields are finally adjusted in Equation (A6) by price response factors for harvesting and input application. Again, similar equations average and apply a price response to the food yields, YFA and YFAP.

(A5) $YPERA_{ij}(t) = PSPER_{ij}(t)*YPER1_{ij}(t) + (1 - PSPER_{ij}(t))*YPER2_{ij}(t)$

(A6) $YPER_{ij}(t) = YPERA_{ij}(t)*\left(\frac{PPPC_k(t)}{PPAVH_k(t)}\right)^{SUPRSP_k}*PPLHV_j*(SRIA_k(t))^{ESRIA_j}$

$$SRI_k(t) = \min\left(\left(\frac{PPPC_k(t)}{PPAVH_k(t)}\right)^{SUPRSI}, 1.\right)$$

where:

YPERA = the perennial yields averaged across the substreams--thousands pounds/thousand acre-years

PSPER = the proportion of land in a perennial stream which is in the first substream (Equation (L2))

YPER = the yield of perennials adjusted for a price response--thousands pounds/thousand acre-years

PPPC = the current agricultural producer-processor price (Equation (P9))--thousands £/thousand pounds

PPAVH = a ten-year exponential average of recent agricultural producer-processor prices (Equation (P8))--thousands £/thousand pounds

SUPRSP = the parameter which determines the nature of the supply response of perennial yields (elasticity)

PPLHV = the proportion of perennial land harvested

SRIA = the lagged input application response--dimensionless

ESRIA = exponent regulating the effect of the input response on yields

SRI = the unlagged input application response

SUPRSI = the parameter which determines the nature of the input response (elasticity)

i = indexes the yielding cohorts--i = 1-6

j = indexes the perennial streams--j = 1-8

k = indexes the perennial commodity--k = 1-3.

Note how the price response works. If the current agricultural producer-processor price, PPPC (see the Price Generating component, Equation (P9)), is greater than the exponentially averaged recent prices, for example, the supply response exponent, SUPRSP, will work as follows: if it is zero, the supply is perfectly inelastic; if SUPRSP is positive, an upward sloping supply curve is assumed; if SUPRSP is negative, a negatively sloped supply curve is assumed. The supply response is based on a ten-year moving average of recent prices so that farmers respond to deviations from what might be called a normal price level, where farmers have a ten-year memory of what is "normal."

Food Production

Before computing the output of food, Equation (A7) calculates how much food land is necessary to meet the subsistence demand of the agricultural population and assigns the remainder of the food land to cash food production. A constraint is placed on the amount of food land in production so that it at least covers the amount of land necessary for subsistence food production.

$$\text{(A7)} \quad SUBFDL_k(t) = SUBFDL_k(t-DT) + (DT/SDEL)*\left(\frac{DEMRS_k(t)*SUBLEV_k(t)}{CALY*YFA_k(t)*PYCNS} - SUBFDL_k(t-DT)\right)$$

$$TLFD_k(t) = \max(TLFDU_k(t),\ SUBFDL_k(t))$$

$$CSHFDL_k(t) = TLFD_k(t) - SUBFDL_k(t)$$

where:

SUBFDL = subsistence food land--thousands of acres

DEMRS = demand for calories from the agricultural sector of the population--thousands of calories/year

SUBLEV = the subsistence level, i.e., the proportion of DEMRS that farmers produce themselves (Equation (A3))

CALY = the calorie content of food--thousands of calories/thousand pounds

YFA = the food yield averaged between modern and traditional--thousands pounds/thousand acre-years

PYCNS = the consumable proportion of food produced, after accounting for loss and spoilage

TLFD = total food land--thousands of acres

TLFDU = unconstrained food land (= TLFD of Equation (L3))--thousands of acres

CSHFDL = cash food land--thousands of acres

SDEL = the subsistence food land smoothing lag--years

k = indexes the crop sectors--k = 1-4.

Note that Equation (A7) calculates the subsistence food land requirement and at the same time smoothes changes in that requirement by lagging it a period, SDEL.

The output of food, then, is a function of food yields, food land and food intercropped with perennials. The amounts of food produced for consumption by the agricultural and nonagricultural populations are also computed (see Chapter VIII, Appendix).

$$\text{(A8)}\quad PDCNCF_k(t) = YFAP_k(t)*\left(CSHFDL_k(t) + \sum_{j=1}^{8} YDMIX*\frac{TLPER_{1j}(t)}{3}\right)$$

$$PDCNSF_k(t) = SUBFDL_k(t)*YFA_k(t)$$

$$TFPAG(t) = \sum_{k=1}^{4} PDCNSF_k(t) + \left[\sum_{k=1}^{4} PDCNCF_k(t) - DEMBIO_4(t)\right]*\frac{(TDCFS - DEMCFS)}{TDCFS}$$

$$TFPNAG(t) = \left[\sum_{k=1}^{4} PDCNCF_k(t) - DEMBIO_4(t)\right]*\frac{DEMCFS}{TDCFS}$$

where:

$TLPER_{1j}$ = total perennial land in cohort 1 of stream j--thousands of acres

PDCNCF = the production of cash food--thousands pounds/year

CSHFDL = cash food land--thousands of acres

YFAP = the averaged and price-response-adjusted food yield (Equations (A5) and (A6))--thousands pounds/thousand acre-years

YDMIX = a factor adjusting food yield for food intercropped on land in the first cohort (gestation) of the perennial streams--dimensionless

PDCNSF = production of subsistence food--thousands pounds/year

SUBFDL = subsistence food land--thousands of acres

YFA = averaged food yields (not price adjusted--Equation (A5))--thousands pounds/thousand acre-years

TFPAG = total food produced for agricultural consumption--thousands pounds/year

TFPNAG = total food produced for nonagricultural consumption--thousands pounds/year

$DEMBIO_4$ = demand for food biological materials for replanting the following year (Equation (A26))--thousands pounds/year

DEMCFS = demand for cash food calories from the nonagricultural population--thousands of calories/year

TDCFS = total demand (agricultural and nonagricultural) for cash food calories--thousands of calories/year

k = indexes the crop sectors--k = 1-4.

There are two basic assumptions in these equations: (1) food will be intercropped on one-third of the land in the gestation stage of perennials and this food will be cash food; (2) subsistence food production does not respond to changes in price (except through the subsistence level adjustment in Equations (A1)-(A3)).

Perennial Production

The output of each perennial population stream (and of wild palm from the bush in the Cocoa Sector) is computed in Equation (A9).

$$\text{(A9)} \quad PDCNP_j(t) = \sum_{i=3}^{8} TLPER_{ij}(t)*YPER_{k(i)j}(t)$$

$$PDCNB(t) = PBWP*TLBSH_1(t)*YBWP*\left(\frac{PPPC_2(t)}{PPAVH_2(t)}\right)^{SUPRSB}*PBLHV$$

where:

PDCNP = the production of perennials--thousands pounds/year

TLPER = total land in perennials--thousands of acres

YPER = yield of perennials--thousands pounds/thousand acre-years

PDCNB = palm output from Cocoa Sector bush land--thousand pounds/year

PBWP = the proportion of Cocoa Sector bush land in wild palm production

$TLBSH_1$ = total bush land in the Cocoa Sector--thousands of acres

YBWP = the wild palm yield of bush land--thousands pounds/thousand acre-years

$PPPC_2$ = the current agricultural producer-processor price of oil palm products--thousands £/thousand pounds

$PPAVH_2$ = the exponentially weighted average of recent palm prices--thousands £/thousand pounds

SUPRSB = a parameter determining the price responsiveness of wild palm products (elasticity)

PBLHV = proportion of wild palm normally harvested

k(i) = indexes the producing cohorts--(i = 3-8) → (k(i) = 1-6)

i = indexes the cohorts--(i = 3-5) → the second cohort; (i = 6-8) → the third through fifth cohorts

j = indexes the perennial streams--j = 1-8.

The second cohort (rising yields) is divided into three parts to more accurately compute production outputs during this period of rapidly increasing yields.

Finally, the outputs of perennial population streams of like commodities are added, i.e., cocoa, palm and rubber, as are cash and subsistence food, to get production by commodity (OPT_i).

Marketing

Next, AMPPAP distributes commodity outputs to subsistence consumption, market consumption, processing and export.

(A10) $$OUTSUB_i(t) = SUBP_i(t)*OPT_i(t)$$

$$OUTMKT_i(t) = PLOSS_i*(OPT_i(t) - OUTSUB_i(t))$$

$$SUBP_4(t) = \{\sum_{k=1}^{4} PDCNSF_k(t) + DEMBIO_4(t)\}/OPT_4(t)$$

__where__:

OUTSUB = the portion of output consumed on the farm--thousands pounds/year

SUBP = the proportion of total output that is consumed on the farm

OPT = the total output of a commodity--thousands pounds/year

OUTMKT = the marketable output of each commodity--thousands pounds/year

PLOSS = the proportion of each crop not lost between field and market

$DEMBIO_4$ = demand for food biological materials for planting the following year (Equation (A26))--thousands pounds/year

i = indexes the commodities--i = 1-5.

The only commodity which may be consumed directly on the farm is, by assumption, food. None of the export crops are so consumed. Palm oil <u>is</u> consumed domestically, but only after processing.

The marketable output of each commodity is directed to consumption, processing or export, and the supply of cash food calories is computed to be used by the market component in determining the food prices in the North and South.

(A11) $OMCNS_i(t) = POMC_i*OUTMKT_i(t)$

$OMPRC_i(t) = POMP_i*OUTMKT_i(t)$

$OMXPT_i(t) = POMX_i*OUTMKT_i(t)$

$SUPCFS(t) = CALY*OMCNS_4(t)*PYCNS$

<u>where</u>:

OMCNS = marketed output consumed directly--thousands pounds/year

POMC = proportion of marketed output that is consumed

OMPRC = marketed output processed--thousands pounds/year

POMP = proportion of marketed output that is processed

OMXPT = marketed output exported directly--thousands pounds/year

POMX = proportion of marketed output that is exported

SUPCFS = supply of cash food in the South (see the food market component in Chapter VIII, Appendix)--thousands of calories/year

CALY, PYCNS = defined in Equation (A7)

i = indexes the commodities--i = 1-5.

Processing

Processing capacity for each commodity is assumed flexible enough to always be greater than the smoothed input of raw materials. The extent of modernization determines how much greater.

(A12) $C_i(t) = PCT_i*PRT_i(t-DT) + PCM_i*PRM_i(t-DT)$

$PCAP_i(t) = \max[C_i(t)*PRMS_i(t), PCAP_i(t-DT)]$

<u>where</u>:

C = a proportion greater than 1

PCT = a proportion greater than 1 for traditional processing

PCM = a proportion greater than 1 for modern processing

PRT = proportion of total processing capacity that is traditional

PRM = proportion of total processing capacity that is modern

PCAP = total processing capacity--thousands pounds (of input)/year

PRMS = smoothed raw material input--thousands pounds/year

i = indexes the commodities processed--i = 1-3.

Thus, increasing production will see increasing processing capacity to handle it. Decreasing production will only lower capacity, however, if excess capacity (exponentially averaged) exceeds some critical value.

(A13) $XESCAP_i(t) = PCAP_i(t) - RM_i(t)$

$$PXSCA_i(t) = PXSCA_i(t-DT) + \frac{DT}{DELXS}(XESCAP_i(t) - PXSCA_i(t-DT))$$

<u>where</u>:

XESCAP = excess capacity--thousands pounds/year

RM = unsmoothed raw material input--thousands pounds/year

PXSCA = exponentially averaged excess capacity--thousands pounds/year

DELXS = the averaging lag time--years

i = indexes the commodities processed--i = 1-3.

If excess capacity exceeds the critical value (a proportion of total capacity), capacity is reduced by stopping replacement investment.

(A14) $DCAP_i(t) = C_i(t)*PRMS_i(t)$

$$PCAP_i(t) = \max(\{PCAP_i(t) - [PRT_i(t-DT)*PDT_i*(\frac{PREPIT_i(t-DT)}{PKCRT_i}) + PRM_i(t-DT)$$

$$*PDM_i*(\frac{PREPIM_i(t-DT)}{PKCRM_i})]*DT\}, DCAP_i(t))$$

$$CAPMD_i(t) = PRM_i(t-DT)*PDM_i*(\frac{PREPIM_i(t-DT)}{PKCRM_i})*DT$$

<u>where</u>:

DCAP = desired capacity--thousand pounds/year

PREPIT = replacement investment in traditional capacity (see Equation (A18))--thousands £/year

PREPIM = replacement investment in modern capacity--thousands £/year

PKCRT = capital-traditional capacity ratio--thousands £-years/thousand pounds

PKCRM = capital-modern capacity ratio--thousands £-years/thousand pounds

CAPMD = decrease in modern capacity--thousands pounds/year

PDT, PDM = parameters (which may be given values of 0, 1 or reciprocals of PRT and PRM, respectively) controlling the contributions to the decrease in total capacity from traditional and modern processing--dimensionless

i = indexes the commodities processed--i = 1-3.

Modernization of processing takes place by direct, exogenous net investment in modern capacity. Modern capacity is constrained by total capacity.

$$\text{(A15)} \quad PCAPM_i(t) = \min[\{PCAPM_i(t-DT) + DT*(\frac{PINVM_i(t-DT) - PREPIM_i(t-DT)}{PKCRM_i}) - CAPMD_i(t)\},\ PCAP_i(t)]$$

where:

PCAPM = modern processing capacity--thousands pounds/year

PINVM = gross investment in modern capacity--thousands £/year

i = indexes the commodities processed--i = 1-3.

Traditional capacity is computed as the difference between total and modern capacities. Thus, the model assumes that modern capacity is created from the conversion of traditional capacity rather than from a net increase in total capacity.

$$\text{(A16)} \quad PCAPT_i(t) = PCAP_i(t) - PCAPM_i(t)$$

where:

PCAPT = traditional processing capacity--thousands pounds/year.

Replacement investment is assumed equal to the depreciation of capital stock, where capital stock is the time integral of net investment, including maintenance. Similar equations compute capital stock and replacement investment for modern processing capacity, where the suffixes "T" are replaced by "M."

$$\text{(A17)} \quad PCAPIT_i(t) = \max\{[PCAPIT_i(t-DT) + DT*(PINVT_i(t-DT) - PREPIT_i(t-DT)],\ 0\}$$

$$PREPIT_i(t) = PDRT_i*PCAPIT_i(t)$$

where:

PCAPIT = capital invested (stock) in traditional processing--thousands £

PDRT = depreciation rate for traditional processing--proportion/year

i = indexes the commodities processed--i = 1-3.

Investments in traditional (and modern, if exogenous modernization ceases) capacity are computed by Equations (A18).

(A18) $PINVT_i(t) = PREPIT_i(t) + \frac{1}{DT}*(PCAPT_i(t) - PCAPT_i(t-DT))*PKCRT_i$

$PINVM_i(t) = PREPIM_i(t) + \frac{1}{DT}*(PCAPM_i(t) - PCAPM_i(t-DT))*PKCRM_i$

where:

PINVT = investment in traditional processing capacity--thousands £/year

PINVM = investment in modern processing capacity--thousands £/year.

The amount of raw material input processed is constrained by capacity and processing losses and waste.

(A19) $RMA_i(t) = \min(RM_i(t), PCAP_i(t))$

$NRMA_i(t) = PCL_i(t)*RMA_i(t)$

where:

RMA = constrained raw material input--thousands pounds/year

NRMA = input processed (not wasted or lost)--thousands pounds/year

PCL = proportion not lost or wasted.

One or two outputs may then be derived from an input, depending on the particular commodity. For example, palm fruit is processed into palm oil and kernels, while rubber latex becomes only sheets.

(A20) $POUT1_i(t) = NRMA_i(t)*PROP1_i(t)$

$POUT2_i(t) = NRMA_i(t)*PROP2_i(t)$

where:

POUT1 = the first processed output--thousands pounds/year

PROP1 = the proportion of input going to the first output

POUT2 = the second processed output--thousands pounds/year

PROP2 = the proportion of input going to the second output.

The loss and input/output proportions are weighted between traditional and modern capacities.

(A21) $PCL_i(t) = PCLM_i*PRM_i(t) + PCLT_i*PRT_i(t)$

$PROP1_i(t) = PROP1M_i*PRM_i(t) + PROP1T_i*PRT_i(t)$

$PROP2_i(t) = PROP2M_i*PRM_i(t) + PROP2T_i*PRT_i(t)$

where:

PCLM, PCLT = proportions of input weight not lost in modern and traditional processing, respectively

PROP1M, PROP1T = proportions of input going to the first output in modern and traditional processing, respectively

PROP2M, PROP2T = proportion of input going to the second output in modern and traditional processing, respectively

PRM, PRT = proportions of total capacity that are modern and traditional, respectively.

Domestic consumption and export of processed outputs are computed by Equation (A22).

(A22) $OPXPT_j(t) = POPX_j(t)*POUT1_i(t)(\text{or } POUT2_i(t))$

$OPCNS_j(t) = POPC_j(t)*POUT1_i(t)(\text{or } POUT2_i(t))$

where:

OPXPT = processed output exported--thousands pounds/year

POPX = proportion of processed output that is exported

OPCNS = processed output consumed domestically--thousands pounds/year

POPC = proportion of processed output that is consumed domestically

i = indexes the raw material input commodities--i = 1-3

j = indexes the processed output commodities--j = 1-4.

In the case of palm oil, these proportions are determined endogenously. Fixed proportions are assumed for rubber and tobacco.

(A23) $$DEMPO(t) = \{\sum_{m=1}^{2} POCNS_m*(TPOPAG_m(t) + TPOPNA_m(t))\}*[\frac{PPRCM_2(t)}{PPOMI}]^{EDPO}$$

$$POPC_1(t) = \min\left(\frac{DEMPO(t)}{SUPPO(t)}, 1\right)$$

$$POPX_1(t) = 1. - POPC_1(t)$$

<u>where</u>:

POCNS = per capita consumption of palm oil--thousands £/thousand person-years

TPOPAG, TPOPNA = total agricultural and nonagricultural population, respectively--thousands of persons

DEMPO = the domestic demand for palm oil--thousands pounds/year

SUPPO = the total supply of palm oil (= POUT1 for palm products)--thousands pounds/year

$PPRCM_2$ = market price of palm oil

PPOMI = initial market price of palm oil

EDPO = elasticity of demand for palm oil

m = indexes the regions--m = 1-2.

The rubber sheets produced and processed as above are smallholder outputs. This output is ratioed up to reflect the contribution of rubber estates and plantations. It is assumed this contribution will approach 50 percent of smallholder production, with time.

$$\text{(A24)} \quad RUBESF(t) = RUBESF(t-DT) + \frac{DT}{15} * (.5 - RUBESF(t-DT))$$

$$XPT_4(t) = OPXPT_3(t) * (1 + RUBESF(t))$$

<u>where</u>:

RUBESF = rubber estates factor--dimensionless

XPT_4 = rubber exports--thousands pounds/year.

Input Demands and Accounting

Production input demands are calculated by Equations (A25) and (A26). First, demands for labor by commodity and by crop sector are generated. The first equation shown is for the perennials produced in the Rubber-Palm Sector. The other perennial sectors are similar. Labor is assumed not to be a constraint. Any shortage will be made up by seasonal migration from the North.

(A25) $$DEMLSP_{3i}(t) = \sum_{j=j(i)}^{j(i)+1} \{[\sum_{n=1}^{5} (PLA1_{jn}*PSPER_{jn}(t) + PLA2_{jn}*(1 - PSPER_{jn}(t))) *TLPER_{jn}(t)] + PLY_j*PDCNP_j(t)\},\ i = 2,3$$

$$DEMLSP_{k4}(t) = [FDLAB1*PSFD_k(t) + FDLAB2*(1 - PSFD_k(t))]*TLFD_k(t) + FDLABY *[PDCNSF_k(t) + PDCNCF_k(t)]$$

$$DEMLS_k(t) = \sum_{i=1}^{5} DEMLSP_{ki}(t)$$

$$DEMLP_i(t) = \sum_{k=1}^{4} DEMLSP_{ki}(t)$$

$$TLABD(t) = \sum_{k=1}^{4} \sum_{i=1}^{5} DEMLSP_{ki}(t)$$

where:

DEMLSP = demand for labor by sector and commodity--thousands of man-units/year

j(i) = indexes the traditional perennial stream corresponding to commodity i in Sector 3 (i = 2 = palm → j(i) = 7; i = 3 = rubber → j(i) = 5)

PLA1, PLA2 = labor input requirements in each cohort of the first and second perennial substreams, respectively--thousands of man-units/thousand acre-years

PSPER = proportion of land in the first substream of a perennial population stream, by cohort (see component LAMDAP)

TLPER = land in each cohort of a perennial population stream (see component LAMDAP)--thousands of acres

PLY = labor required for perennial harvesting--thousands of man-units/thousand pounds

PDCNP = output of perennial stream (Equation (A9))--thousands pounds/year

FDLAB1, FDLAB2 = labor input requirements for traditional and modern food, respectively--thousands of man-units/thousand acre-years

FDLABY = labor required for harvesting food--thousands of man-units/thousand pounds

PSFD = proportion of food land which is traditional

TLFD = total food land--thousands of acres

PDCNSF, PDCNCF = production of subsistence and cash food, respectively--thousands pounds/year

DEMLS = labor demand by crop sector--thousands of man-units/year

DEMLP = labor demand by commodity--thousands of man-units/year

TLABD = total agricultural labor demanded in the South--thousands of man-units/year

i = indexes the commodities--i = 1-5

k = indexes the crop sectors--k = 1-4

j = indexes the perennial streams--j = 1-8

n = indexes the perennial cohorts--n = 1-5.

Chemical, capital and biological inputs are computed by Equation (A26). The equations are given for cocoa and food. The other perennials are similar.

$$\text{(A26)}\quad DEMCH_1(t) = \sum_{j=1}^{2} \sum_{n=1}^{5} (PCA1_{jn}*PSPER_{jn}(t) + PCA2_{jn}*(1 - PSPER_{jn}(t)))*TLPER_{jn}(t)$$

$$DEMCH_4(t) = \sum_{k=1}^{4} [FDCH1*PSFD_k(t) + FDCH2*(1 - PSFD_k(t))]*TLFD_k(t)$$

$$CAPDEP_4(t) = \sum_{j=1}^{2} EQPER_j*\left(\sum_{n=1}^{5} TLPER_{jn}(t)\right)$$

$$CAPDEP_4(t) = \sum_{k=1}^{4} EQFD*TLFD_k(t)$$

$$DEMBIO_1(t) = EBIOT_1*RINPT1_1(t) + EBIOM_1*RINPM1_1(t)$$

$$DEMBIO_4(t) = FDBIO*\sum_{k=1}^{4} [TLFD_k(t) + (RINF_k(t) - ROUTF_k(t))*DT]$$

<u>where</u>:

CAPDEP = capital invested (depreciation = equipment replacement) in a commodity--thousands £/year

EQPER, EQFD = equipment (capital) costs for perennial and food production, respectively--thousands £/thousand acre-years

DEMCH = the demand for chemicals to produce a commodity--thousands pounds/year

PCA1, PCA2 = the per-acre chemical requirement of the first and second perennial substreams, respectively--thousands pounds/thousand acre-years

FDCH1, FDCH2 = the per-acre chemical requirement of traditional and modern food, respectively--thousands pounds/thousand acre-years

DEMBIO = the demand for biological inputs--thousands of units/year

EBIOT, EBIOM, FDBIO = biological input rate for traditional and modern perennials and food, respectively--thousands of units/thousand acre-years

RINPT1, RINPM1 = planting rate of traditional and modern perennials, respectively (component LAMDAP, Equation (L1))--thousands of acres/year

RINF, ROUTF = rate land enters and leaves food production, respectively (component LAMDAP, Equation (L3))--thousands of acres/year.

Processing capital is calculated in Equations (A17) above. Chemicals and labor for processing and labor for marketing are computed in Equations (A27). No marketing labor is assumed necessary for the portion of production output which is wasted or lost in processing.

(A27) $EMPPM_k(t) = RMA_k(t)*PRM_k(t)*PLIRM_k$

$$EMPPT_k(t) = RMA_k(t)*PRT_k(t)*PLIRT_k$$

$$VALCHP_k(t) = PCHT_k(t)*OPCT_k(t) + PCHM_k(t)*OPCM_k(t)$$

$$PWLOSS_i(t) = [1 - POMP_i*(1 - PCL_i(t))]*\min[\frac{PCAP_k(t)}{OMPRC_i(t)}, 1]$$

$$DEMLM_i(t) = OLABM_i(t)*OUTMKT_i(t)*PWLOSS_i(t)$$

<u>where</u>:

EMPPM, EMPPT = modern and traditional processing labor, respectively--thousands of man-units/year

PLIRM, PLIRT = labor input requirements for modern and traditional processing, respectively--thousands of man-units/thousand pounds

VALCHP = the value of chemical inputs to processing--thousands £/year

PCHT, PCHM = proportions of traditional and modern processing operating costs, respectively, that are chemical inputs

OPCT, OPCM = traditional and modern processing operating costs, respectively, (see Equation (A30) below)--thousands £/year

PWLOSS = processing weight loss factor--dimensionless

DEMLM = demand for labor in the marketing sector--thousands of units/year

OLABM = the labor required to market a pound of produce--thousands of man-units/thousand pounds

OMPRC = marketable output processed (Equation (A11))

OUTMKT = marketed production output--thousands pounds/year

PCAP = processing capacity (Equation (A14))

POMP = defined in Equation (A11)

PCL = defined in Equation (A19)

k = indexes processed commodities

i = indexes produced commodities.

The accounting and criteria variables for agricultural production and marketing are computed in Equation (A28) for each commodity. The capitalized value equation is given for food; the values of the other commodities are similarly computed.

(A28) $WAG_i(t) = PL*DEMLP_i(t)*PLHP_i(t)$

$$WMKT_i(t) = PLM*DEMLM_i(t)$$

$$COSTML_i(t) = OLABM_i*\frac{PLM}{PPRCM_i(t)}$$

$$CCBEI_i(t) = PCI_i*DEMCH_i(t) + PBI_i*DEMBIO_i(t) + CAPDEP_i(t)$$

$$REVSUB_i(t) = PPRC_i(t)*OUTSUB_i(t)$$

$$REVCSH_i(t) = PPRC_i(t)*OUTMKT_i(t)*(\frac{PSOLD_i(t)}{PLOSS_i})$$

$$VALADP_i(t) = PPRC_i(t)*OPT_i(t) - (CCBEI_i(t) - CAPDEP_i(t))$$

$$VALADM_i(t) = PPRCM_i(t)*OUTMKT_i(t)*PSOLD_i(t)*PWLOSS_i(t) - REVCSH_i(t)$$
$$*(1 - POMP_i) - PINC_i(t)$$

$$REVCN_i(t) = REVCSH_i(t) - CCBEI_i(t) - WAG_i(t) + PAGREV_i(t)$$

$$TAXMS(t) = \max[TAXMR_i*(PPRCM_i(t)*OUTMKT_i(t)*PSOLD_i(t)*PWLOSS_i(t)$$
$$- WMKT_i(t)), 0]$$

$$TAXPS_i(t) = \max[TAXPR_i * (REVCN_i(t) - PAGREV_i(t)), 0]$$

$$PRFT_i(t) = PPRC_i(t) * OPT_i(t) - CCBEI_i(t) - TAXPS_i(t) - WAG_i(t) + PAGREV_i(t) - PTAX_i(t)$$

$$PRFTM_i(t) = PPRCM_i(t) * OUTMKT_i(t) * PSOLD_i(t) * PWLOSS_i(t) - WMKT_i(t) - TAXMS_i(t) - REVCSH_i(t) * (1 - POMP_i) - PINC_i(t)$$

$$PRFTLB_i(t) = (PRFT_i(t) + WAG_i(t))/DEMLP_i(t)$$

$$PRFTLD_i(t) = PRFT_i(t)/TLD_i(t)$$

$$CAPVAL_4(t) = \frac{1}{RI} * \max[(PRFT_4(t) + TAXPS_4(t) + PTAX_4(t)), 0]$$

<u>where</u>:

WAG = cash wages paid--thousands £/year

PL = wage rate in the agricultural sector--thousands £/thousand man-units

PLHP = proportion of labor which is hired (Equation (A29) below)

WMKT = wages paid in the marketing sector--thousands £/year

PLM = wage rate in the marketing sector--thousands £/thousand man-units

COSTML = marketing labor costs (to be used in the price generating component)--proportion of market price

PPRCM = market price--thousands £/thousand pounds

CCBEI = cost of chemical capital and biological inputs--thousands £/year

PCI = the price of chemical inputs--thousands £/thousand pounds

PBI = the price of biological inputs--thousands £/thousand units

REVSUB = revenue in kind--thousands £/year

PPRC = producer price--thousands £/thousand pounds

PSOLD = proportion of output sold (see Equation (A30) below)

PLOSS = proportion of output not lost between field and market

PWLOSS = processing weight loss (Equation (A27))--dimensionless

REVCSH = cash revenue--thousands £/year

VALADP = value added in the production sector--thousands £/year

VALADM = value added in the marketing sector--thousands £/year

PPRCM = market price--thousands £/thousand pounds

REVCN = net cash revenue--thousand £/year

PAGREV = processing revenue to the agricultural sector (see Equation (A32))--thousands £/year

TAXPS = tax revenue from the production sector--thousands £/year

TAXPR = tax rate in the production sector

TAXMS = tax revenue from the marketing sector--thousands £/year

TAXMR = tax rate in the marketing sector

PTAX = tax revenue from processing (see Equation (A32))--thousands £/year

PRFT = profit in the production sector--thousands £/year

PRFTM = profit in the marketing sector--thousands £/year

POMP = defined in Equation (A11)

PINC = gross income to agricultural processing (see Equation (A30) below)--thousands £/year

PRFTLB = returns to labor--thousands £/thousand man-years

PRFTLD = returns to land--thousands £/thousand acre-years

CAPVAL = capitalized value of commodity land--thousands £

RI = interest rate--proportion/year

i = indexes the commodities--i = 1-5.

The proportions of labor hired by commodity and by crop sector are functions of nonfamily indigenous labor and seasonal migration.

$$\text{(A29)}\quad PLHIRE_k(t) = \max\left[\frac{DEMLS_k(t) - LABAS_k(t)}{DEMLS_k(t)}, 0\right] + \sum_{i=1}^{5} PNFL_i * \frac{DEMLSP_{ki}(t)}{DEMLS_k(t)}$$

$$PLHP_i(t) = PNFL_i + \sum_{k=1}^{4} \max\left[\frac{DEMLS_k(t) - LABAS_k(t)}{DEMLS_k(t)}, 0\right] * \frac{DEMLSP_{ki}(t)}{DEMLP_i(t)}$$

$$RSMIGL(t) = \max\left\{\left[TLABD(t) - \sum_{k=1}^{5} LABAS_k(t)\right], 0\right\}$$

<u>where</u>:

DEMLS = defined in Equation (A25)

DEMLSP = defined in Equation (A25)

DEMLP = defined in Equation (A25)

TLABD = defined in Equation (A25)

LABAS = labor supply (from the population component)--thousands of man-units/year

PNFL = proportion of a commodity's labor requirements hired from the indigenous (to a crop sector) population--a model parameter

PLHIRE = proportion of labor hired (including migration into the crop sector) by crop sector

PLHP = proportion of labor hired (including migration) by commodity

RSMIGL = seasonal labor migration into the South--thousands of man-units/year

i = indexes the commodities--i = 1-5

k = indexes the crop sectors--k = 1-4.

The proportion of food output sold is the demand-supply ratio constrained so as not to exceed 1. The proportion of the other commodities sold is assumed fixed and equal to 1.

(A30) $PSOLD_4(t) = \min\left(\frac{TDCFS(t)}{SUPCFS(t)}, 1.\right)$

<u>where</u>:

TDCFS = total demand for cash food--thousands of calories/year

SUPCFS = supply of cash food (Equation (A11))--thousands of calories/year.

Accounting equations similar to Equation (A28) are computed for the processing, traditional and modern, of each agricultural commodity. Similar equations are executed for modern processing, where the suffixes "T" are replaced by "M."

(A31) $PINC_i(t) = POUT1_i(t)*PPRCP1_i(t) + POUT2_i(t)*PPRCP2_i(t)$

$INCT_i(t) = PRT_i(t)*PINC_i(t)$

$WAGEST_i(t) = EMPPT_i(t)*PWRT_i*PPNFLT_i$

$VOIT_i(t) = RMA_i(t)*PRT_i(t)*PPRC_i(t)$

$OPCT_i(t) = RMA_i(t)*PRT_i(t)*POCUT_i$

$$GROSPT_i(t) = INCT_i(t) - OPCT_i(t) - PREPIT_i(t) - WAGEST_i(t) - VOIT_i(t)$$

$$TAXT_i(t) = GROSPT_i(t)*TRPT_i + INCT_i(t)*TRIT_i$$

$$VALADT_i(t) = INCT_i(t) - OPCT_i(t) - VOIT_i(t)$$

where:

PINC = gross processing income--thousands £/year

PPRCP1(PPRCP2) = processor price of the first (second) processed output of a commodity--thousands £/thousand pounds

POUT1(POUT2) = the first (second) processed output of a commodity (Equation (A20))--thousands £/year

INCT = income to traditional processing--thousands £/year

PRT = the proportion of total processing capacity that is traditional

WAGEST = cash wages paid in traditional processing--thousands £/year

EMPPT = labor demand for traditional processing (Equation (A20))--thousands of man-units/year

PPNFLT = proportion of nonfamily (hired) labor used in traditional processing--a model parameter

PWRT = wage rate in traditional processing--thousands £/thousand man-units

VOIT = cost of raw material inputs--thousands £/year

RMA = actual raw material input (Equation (A19))--thousands £/year

PPRC = producer price--thousands £/thousand pounds

OPCT = operating cost of traditional processing--thousands £/year

POCUT = operating cost rate--thousands £/thousand pounds

GROSPT = gross profit in traditional processing--thousands £/year

PREPIT = replacement investment in traditional processing (Equation (A17))--thousands £/year

TAXT = taxes paid from traditional processing--thousands £/year

TRPT(TRIT) = profits (income) tax rate for traditional processing

VALADT = value added in traditional processing--thousands £/year

i = indexes the commodities processed--i = 1-3.

Finally, totals are made across traditional and modern processing, and returns to the agricultural production sector are computed.

(A32) $PTAX_i(t) = TAXT_i(t) + TAXM_i(t)$

$PVALAD_i(t) = VALADT_i(t) + VALADM_i(t)$

$PRFTP_i(t) = GROSPT_i(t) + GROSPM_i(t) - PTAX_i(t)$

$PACREV_i(t) = GROSPT_i(t)*PAGT + GROSPM_i(t)*PAGM_i$

where:

PTAX = total taxes paid from agricultural processing--thousands £/year

PVALAD = total value added in agricultural processing--thousands £/year

PRFTP = profits from agricultural processing--thousands £/year

PAGREV = returns to the agricultural sector from agricultural processing--thousands £/year

PAGT(PAGM) = proportion of traditional (modern) processing performed by the agricultural sector--a model parameter

i = indexes the commodities processed--i = 1-3.

Component PG

The price generation component computes world, market, processor and producer prices and exponential averages of producer prices and price trends. Each step (Figure 5.8 in the chapter) is assumed to have a pricing advantage over the next lower step.

Equation (P1) computes exogenous world prices.

$$(P1)\quad WP_i(t) = \begin{cases} VALWP_{1i} + \frac{t}{13}*(VALWP_{13i} - VALWP_{1i}), & 0 < t \leq 13 \\ VALWP_{13i} + \frac{t-13}{4}*(WP1970_i - VALWP_{13i}), & 13 < t \leq 17 \\ WP1970_i*(1 + WPR_i*(t-17)), & t > 17 \end{cases}$$

where:

WP = world (F.O.B.) price--thousands £/thousand pounds

$VALWP_{ki}$ = actual world prices at time k, k = 1953, 1954, ..., 1965

WP1970 = actual world price in 1970

WPR = rate of change of world price after 1970--proportion/year

t = simulated time--years

i = indexes the export commodities--i = 1-4.

Equation (P2) computes the price received by the marketing boards (or other export marketers, in the case of rubber). The market price for food is determined endogenously in the market component of the national model, while the tobacco price to the tobacco company is an exogenous parameter.

(P2) $PPRCM_i(t) = WP_i(t)*(1 - EXTAX_i)$

where:

PPRCM = market price--thousands £/thousand pounds

EXTAX = export tax--a proportion of world price

i = indexes the export commodities (except palm oil)--i = 1,3,4.

Since palm oil has a domestic market, the market price is constrained by Equation (P3) to be the maximum of a domestic price and the price the marketing board receives (based on world prices).

(P3) $PPRCM_2(t) = \max[WP_2(t)*(1 - EXTAX_2), DPPO(t-DT)]$

where:

DPPO = domestic market price of palm oil (Equation (P4))--thousands £/thousand pounds.

The domestic price of palm oil, DPPO, is computed from Equations (P4).

$$(P4)\quad DPPOU(t) = \begin{cases} DPPOU(t-DT) + DT*CPPO*DPPOU(t-DT)*\left(\dfrac{DEMPO(t) - SUPPO(t)}{DEMPO(t)}\right) & \text{if } DEMPO \geq SUPPO \\ PPRCM(t) & \text{if } DEMPO < SUPPO \end{cases}$$

$$DPPO(t) = DPPO(t-DT) + \frac{DT}{PPODEL}*[DPPOU(t) - DPPO(t-DT)]$$

where:

DEMPO = the domestic demand for palm oil (component AMPPAP, Equation (A23))--thousands pounds/year

DPPOU = the unlagged domestic palm oil market price--thousands £/thousand pounds

CPPO = a parameter regulating the price response to excess demand--proportion/year

SUPPO = total supply of palm oil (from AMPPAP)--thousands pounds/year

PPODEL = smoothing lag--years.

Note that the market price of palm oil will exceed $PPRCM_2$ as computed in Equation (P2) only if domestic demand exceeds total supply.

From the market price, Equation (P5) computes the price received by the processors.

(P5) $PPRCP_i(t) = PPRCM_i(t)*(1 - SRPMB_i - COSTM_i - COSTML_i(t) - TAXMR_i)$

<u>where</u>:

PPRCP = processor price--thousands £/thousand pounds

SRPMB = marketing board (or other marketer) profits--proportion of market price

COSTM = marketing costs--proportion of market price

COSTML = marketing labor costs (component AMPPAP, Equation (A28))--proportion of market price

TAXMR = marketing tax rate--proportion of market price

i = indexes the commodities marketed--i = 1, 3-6.

Again, palm oil is a special case to account for both the export and domestic markets.

(P6) $PPRCP_2(t) = PPRCM_2(t)*[1 - TAXMR_2 - (SRPMB_2 + COSTM_2 + COSTML_2(t))*POPX_2(t)$

$- (SRPMB_5 + COSTM_5 + COSTML_5(t))*POPC_2(t)]$

<u>where</u>:

POPX = the proportion of processed palm oil exported (component AMPPAP, Equation (A23))

POPC = the proportion of processed palm oil consumed domestically (= 1 - POPX)

2 = indexes palm oil

5 = indexes food.

Note that the domestic marketing of palm oil is assumed to have the same costs and profit margins as food.

Next, producer prices are computed in Equation (P7). Since two palm commodities are processed outputs of one production input (palm fruit bunches), the processor prices for kernels and oil are averaged to determine the producer prices. The variable, $PPRCPP_2$, then, is this weighted average. The others, $PPRCPP_i$, i = 1, 3-5, are simply equal to the corresponding PPRCP, j = 1, 4-6. For those commodities not processed (cocoa and food), the producer price equals the processor price.

(P7) $PPRC_i(t) = PPRCPP_i(t)*(1 - TAXPPR_i - COSTP_i(t) - PSRP_i(t))*PCL_i(t)$

<u>where</u>:

PPRC = producer price--thousands £/thousand pounds produced

PPRCPP = processor price (weighted between processed outputs)--thousands £/ thousand pounds processed

TAXPPR = processing tax rate--proportion of price

COSTP = processing costs (computed from the processing costs determined in component AMPPAP, Equation (A31))--proportion of price

PSRP = processing profit margin (weighted between traditional and modern processing margins)--proportion of price

PCL = processing loss factor--thousands pounds processed/thousand pounds produced

i = indexes the commodities produced--i = 1-5.

Finally, exponential price and price trend averages are computed in Equation (P8) for use in determining land allocation decisions (component LAMDAP) and harvest supply responses (component AMPPAP).

(P8) $$PPAV_i(t) = PPAV_i(t-DT) + \frac{DT}{PRCDEL}*[PPPC_i(t) - PPAV_i(t-DT)]$$

$$PPAVH_i(t) = PPAVH_i(t-DT) + \frac{DT}{PRCDLH}*[PPPC_i(t) - PPAVH_i(t-DT)]$$

$$PPAVR_i(t) = PPAVR_i(t-DT) + \frac{DT}{PRCDEL}*[\frac{PPPC_i(t)}{PPPC_i(t-DT)} - PPAVR_i(t-DT)]$$

<u>where</u>:

PPAV = exponential average of agricultural producer-processor prices used in LAMDAP--thousands £/thousand pounds

PPAVH = exponential average of producer-processor prices used in AMPPAP--thousands £/thousand pounds

PPPC = agricultural producer-processor prices (see Equation (P9))--thousands £/thousand pounds

PPAVR = producer-processor price trends--dimensionless

PRCDEL = averaging lag--years

PRCDLH = averaging lag--years

i = indexes the commodities produced--i = 1-5.

Since much, if not all, of the processing of agricultural commodities is performed by the agricultural sector itself, the prices used in determining profitabilities for land allocation decisions and harvest price responses are weighted averages of producer prices and processor prices.

(P?) $PPPC_i(t) = PPRC_i(t) + PAG_i(t)*(PPRCPP_i(t)*PCL_i(t) - PPRC_i(t))$

<u>where</u>:

PPPC = producer-processor price--thousands £/thousand pounds

PPRC = producer price

PPRCPP = processor price

PCL = processing loss coefficient

PAG = proportion of agricultural processing done by the agricultural sector itself

i = indexes the commodities--i = 1-5.

<u>Component CRTMBA</u>

Performance Criteria

Equations (C1) through (C5) compute the performance variables of the Southern model. These include: (1) value added, foreign exchange and government revenues; (2) other variables needed for the national accounts/nonagricultural sector model, and (3) capital and modern input demands.

Equation (C1) computes total value added from agricultural production, marketing and processing.

(C1) $$TVAP_2(t) = \sum_{i=1}^{5} VALADP_i(t)$$

$$TVAM_2(t) = \sum_{i=1}^{5} VALADM_i(t)$$

$$TVAPP(t) = \sum_{j=1}^{3} PVALAD_j(t)$$

$$TVAS(t) = TVAP_2(t) + TVAM_2(t) + TVAPP(t)$$

$$ATVAS(t) = ATVAS(t-DT) + DT*TVAS(t)$$

where:

$TVAP_2$ = total value added in agricultural production in the South--thousands £/year

$TVAM_2$ = total value added in agricultural marketing in the South--thousands £/year

TVAPP = total value added in agricultural processing in the South--thousands £/year

VALADP, VALADM, PVALAD = value added by commodity in agricultural production, marketing and processing, respectively (Equations (A28) and (A32))--thousands £/year

TVAS = total value added in agriculture in the South--thousands £/year

ATVAS = accumulated value added--thousands £

DT = simulation time period--years

i = indexes the commodities produced (cocoa, palm, rubber, food, tobacco)

j = indexes the commodities processed (palm, rubber, tobacco).

The value of agricultural exports at F.O.B. and processor prices are computed by Equation (C2).

$$\text{(C2)}\quad VALEXP_2(t) = \sum_{i=1}^{4} WP_i(t)*XPT_i(t)$$

$$VALXPP_2(t) = \sum_{i=1}^{4} PPRCP_i(t)*XPT_i(t)/PLOSS_i$$

$$AFORXS(t) = AFORXS(t-DT) + DT*VALEXP_2(t)$$

where:

$VALEXP_2$ = the value, at F.O.B. prices, of agricultural exports in the South--thousands £/year

$VALXPP_2$ = the value, at processor prices, of agricultural exports in the South--thousands £/year

WP = world (F.O.B.) price (Equation (P1))--thousands £/thousand pounds

PPRCP = processor price (Equation (P5))--thousands £/thousand pounds

XPT = quantity exported (component AMPPAP)--thousands pounds/year

PLOSS = marketing loss factor--proportion

AFORXS = accumulated foreign exchange from agricultural exports in the South--thousands £

i = indexes the export commodities (cocoa, palm oil, palm kernels, rubber).

Government revenues, Equation (C3), include tax revenues and marketing board surpluses.

$$\text{(C3)}\quad TAXAG_2(t) = \sum_{i=1}^{5} [TAXPS_i(t) + TAXMS_i(t) + PTAX_i(t)]$$

$$TTAXGS(t) = TAXAG_2(t) + \sum_{j=1}^{4} WP_j(t)*EXTAX_j*XPT_j(t)$$

$$REVMBS_k(t) = XPT_k(t)*[PPRCM_k(t)*(1. - COSTM_k - COSTML_k(t)) - \frac{PPRCP_k(t)}{PLOSS_k}]$$

$$TMBREV_2(t) = \sum_{k=1}^{3} REVMBS_k(t)$$

$$TMOVHD_2(t) = \sum_{k=1}^{3} XPT_k(t)*PPRCM_k(t)*COSTM_k$$

$$ATTXGS(t) = ATTXGS(t-DT) + DT*TTAXGS(t)$$

$$ATRMBS(t) = ATRMBS(t-DT) + DT*TMBREV_2(t)$$

<u>where</u>:

$TAXAG_2$ = southern agricultural sector tax revenues--thousands £/year

TAXPS, TAXMS, PTAX = producer, market and processor tax revenues, respectively, by commodity (Equations (A28) and (A32))--thousands £/year

EXTAX = export tax rate

TTAXGS = total southern agricultural sector tax revenues--thousands £/year

ATTXGS = accumulated tax revenues--thousands £

REVMBS = marketing board revenues in the South, by commodity--thousands £/year

PPRCM = market price (Equation (P2))--thousands £/thousand pounds

COSTM = marketing overhead factor--proportion of market price

COSTML = marketing wages paid (Equation (A28))--proportion of market price

PPRCP = processor price (Equation (P5))--thousands £/thousand pounds

PLOSS = proportion marketed after losses

$TMBREV_2$ = total marketing board revenues in the South--thousands £/year

$TMOVHD_2$ = total marketing board overhead expenses--thousands £/year

ATRMBS = accumulated marketing board revenues--thousands £

i = indexes the commodities produced

j = indexes the commodities exported

k = indexes the commodities handled by marketing boards (cocoa, palm oil, palm kernels).

Equation (C4) computes other variables needed for the national accounts/ nonagricultural sector model.

$$\text{(C4)} \quad TAXEXP(t) = TTAXGS(t) - TAXAG_2(t)$$

$$VALCP_2(t) = \sum_{i=1}^{5} DEMCH_i(t)*PCI_i$$

$$VALCPP(t) = \sum_{j=1}^{3} VALCHP_j(t)$$

$$CAPDPP(t) = \sum_{j=1}^{3} [PINVT_j(t) + PINVM_j(t)]$$

$$CAPDP_2(t) = \sum_{i=1}^{5} CAPDEP_i(t)$$

where:

TAXEXP = agricultural export tax revenues--thousands £/year

$VALCP_2$ = value of agricultural production chemical input demands in the South--thousands £/year

DEMCH = quantity demand for chemicals, by commodity (Equation (A26))--thousands pounds/year

PCI = price of chemical inputs--thousands £/thousand pounds

VALCPP = value of agricultural processing chemical input demands--thousands £/year

VALCHP = value of agricultural processing chemical input demands, by commodity (Equation (A27))--thousands £/year

CAPDPP = processing capital investment demands--thousands £/year

PINVT, PINVM = investment in traditional and modern processing, respectively, by commodity (Equation (A18))--thousands £/year

$CAPDP_2$ = total investment in agricultural capital equipment in the South--thousands £/year

CAPDEP = agricultural replacement investment in equipment, by commodity (Equation (A26))--thousands £/year

i = indexes the commodities produced

j = indexes the commodities processed.

Finally, Equation (C5) computes input demand totals generated by modernization campaigns and the demand for agricultural net investment.

(C5) $$TCHEMP(t) = \sum_{m=1}^{5} ECHEMP_m(t)$$

$$TCAPMP(t) = \sum_{m=1}^{5} ECAPMP_m(t)$$

$$TCAPRT(t) = \sum_{k=1}^{4} ECAPRT_k(t)$$

<u>where</u>:

TCHEMP = total demand for chemicals from modernization promotion efforts--thousands pounds/year

TCAPMP = total demand for net investment from modernization promotion efforts--thousands £/year

TCAPRT = total agricultural demand for net investment--thousands £/year

ECHEMP = chemical demands, by production campaign (Equation (L15))--thousands pounds/year

ECAPMP = net investment demands, by production campaign (Equation (L15))--thousands £/year

ECAPRT = net investment demands, by crop sector (Equation (L14))--thousands £/year

m = indexes the modernization programs

k = indexes the crop sectors.

Budget Accounting

Agricultural incomes and expenditures, computed in component AMPPAP by commodity (Equation (A28)), are distributed here by crop sector (Equation (C6)). This distribution will be used to determine disposable income, consumption and investment in each crop sector. Only the equations for the Rubber-Palm Sector are given here as an example; the others are quite similar.

(C6) $$PSC_{32}(t) = \frac{(PDCNP_7(t) + PDCNP_8(t))}{OPT_2(t)}$$

$$PSC_{31}(t) = \frac{(PDCNCF_3(t) + PDCNSF_3(t))}{OPT_4(t)}$$

$$AGINC_3(t) = REVCSH_3(t) + REVCSH_2(t)*PSC_{32}(t) + REVCSH_4(t)*PSC_{31}(t) + CRDT_3(t-DT) + CAPDIA_2(t) + CAPDIA_1(t)*PSC_{32}(t)$$

$$SCCBEI_3(t) = CCBEI_3(t) + CCBEI_2(t)*PSC_{32}(t) + CCBEI_4(t)*PSC_{31}(t)$$

$$STAX_3(t) = TAXPS_3(t) + TAXPS_2(t)*PSC_{32}(t) + TAXPS_4(t)*PSC_{31}(t)$$

$$SCV_3(t) = CAPVAL_3(t) + CAPVAL_2(t)*PSC_{32}(t) + CAPVAL_4(t)*PSC_{31}(t)$$

where:

PSC_{32} = proportion of palm fruit produced in Sector 3 (Rubber-Palm Sector)

PSC_{31} = proportion of food produced in Sector 3

$PDCNP_7$, $PDCNP_8$ = output of the traditional and modern palm perennial population streams, respectively, in Sector 3 (Equation (A9))--thousands pounds/year

$PDCNCF_3$, $PDCNSF_3$ = output of cash and subsistence food, respectively, in Sector 3 (Equation (A8))--thousands pounds/year

OPT_2, OPT_4 = total production of palm and food, respectively, in the South--thousands pounds/year

$AGINC_3$ = gross agricultural income in Sector 3--thousands £/year

$REVCSH_3$, $REVCSH_2$, $REVCSH_4$ = gross income from agricultural production of rubber, palm and food, respectively (Equation (A28))--thousands £/year

$CAPDIA_2$, $CAPDIA_1$ = agricultural disposable income derived from agricultural processing of rubber and palm products, respectively (Equation (C13), below)--thousands £/year

$CRDT_3$ = credits granted to the agricultural sector in the Rubber-Palm zone (Equation (C11), below)--thousands £/year

$SCCBEI_3$ = cost of chemical, modern biological and capital equipment inputs to agricultural production in Sector 3--thousands £/year

$CCBEI_3$, $CCBEI_2$, $CCBEI_4$ = cost of chemical, modern biological and capital inputs to rubber, palm and food production, respectively (Equation (A28))--thousands £/year

$STAX_3$ = producer income tax revenues in Sector 3--thousands £/year

$TAXPS_3$, $TAXPS_2$, $TAXPS_4$ = producer income taxes from the production of rubber, palm and food, respectively (Equation (A28))--thousands £/year

SCV_3 = capitalized asset value of cultivated land in Sector 3--thousands £

$CAPVAL_3$, $CAPVAL_2$, $CAPVAL_4$ = capitalized asset value of rubber, palm and food land, respectively (Equation (A28))--thousands £.

Agricultural sector expenditures in each crop sector for nonagricultural goods and services produced within the sector are computed and treated as a multiplier for the agricultural income.

(C7) $$TAGINC_k(t) = \frac{AGINC_k(t)}{(1 - CMUL_{k2})}$$

$$SINAC_k(t) = CMUL_{k2}*TAGINC_k(t)$$

<u>where</u>:

TAGINC = total agricultural income--thousands £/year

$CMUL_2$ = proportion of income consumed within the agricultural sector in the South

SINAC = consumption within the agricultural sector--thousands £/year

k = indexes the crop sectors--k = 1-4.

The debt service, debt and interest payments in the agricultural sector accounts are computed by Equation (C8).

(C8) $$SDS_k(t) = \max[(SDSR_k*SDBT_k(t-DT)), 0.]$$

$$SINT_k(t) = RI*SDBT_k(t-DT)$$

$$SDBT_k(t) = SDBT_k(t-DT) + DT*\{CRDT_k(t-DT) - SDS_k(t) + \max[-(SAGDIU_k(t) - CNSMIN_k(t)), 0\}$$

<u>where</u>:

SDS = debt service paid--thousands £/year

SDSR = repayment rate--proportion of debt/year

SDBT = agricultural sector debt--thousands £

CRDT = agricultural sector credits (Equation (C11), below)--thousands £/year

SINT = interest payments--thousands £/year

RI = interest rate on agricultural production loans--proportion of debt/year

SAGDIU = agricultural disposable income (Equation (C9), below)--thousands £/year

CNSMIN = subsistence nonfood consumption (Equation (C9))--thousands £/year

k = indexes the crop sectors--k = 1-4.

Agricultural disposable income, finally, is the gross income net of costs and food expenditures. It is constrained to be non-negative, any negative portion adding to the debt.

(C9) $$SAGDIU_k(t) = TAGINC_k(t) - SDS_k(t) - SINT_k(t) - SCCBEI_k(t) - STAX_k(t) - SINAC_k(t) - DEMRS_k(t)*(1 - SUBLEV_k(t))*PRFD_2(t)/(CALY*PYCNS)$$

$$CNSMIN_k(t) = TPOPAG_2(t)*DLABOR_{k12}*PCCNS_k$$

$$SAGDI_k(t) = \max[SAGDIU_k(t), CNSMIN_k(t)]$$

<u>where</u>:

SAGDIU = unconstrained disposable income--thousands £/year

CNSMIN = subsistence nonfood consumption--thousands £/year

$TPOPAG_2$ = agricultural sector population--thousands of people

$DLABOR_{12}$ = proportion of southern labor force in cash crop sector

PCCNS = per capita subsistence nonfood consumption--thousands £/thousand people-year

SAGDI = constrained disposable income--thousands £/year

DEMRS, SUBLEV, CALY = see definitions under Equation (C4), above

$PRFD_2$ = market price of food in the South (from the market component)--thousands £/thousand pounds

PYCNS = proportion of marketed food that is consumed

k = indexes the crop sectors--k = 1-4.

Investment and consumption expenditures are determined from disposable income by the average propensity to consume. Any available investment capital so computed, which is in excess of investment demands, is added to consumption.

$$\text{(C10)}\quad SAGDII_k(t) = (1 - APC)*SAGDI_k(t)$$

$$SAGDIC_k(t) = APC*SAGDI_k(t) + \max[0., -(ECAPRT_k(t) - SAGDII_k(t))]$$

$$TAGDIP_2(t) = \sum_{k=1}^{4} SAGDIC_k(t)$$

<u>where</u>:

SAGDII = agricultural income available for investment--thousands £/year

SAGDIC = agricultural income available for consumption--thousands £/year

APC = agricultural average propensity to consume--proportion of income

ECAPRT = agricultural demand for net investment (Equation (L13))--thousands £/year

$TAGDIP_2$ = total agricultural consumption in the South--thousands £/year

k = indexes the crop sectors.

Credit received for agricultural investment is constrained to be no more than the credit available (determined by the equity value of the land holdings), and the excess demand for investment, whichever is less.

$$\text{(C11)}\quad CRDTAV_k(t) = PEQCR*(SCV_k(t) - SDBT_k(t))$$

$$CRDT_k(t) = \min\{CRDTAV_k(t), \max[(ECAPRT_k(t) - SAGDII_k(t)), 0.]\}$$

$$TDCTS(t) = \sum_{k=1}^{4} CRDT_k(t)$$

<u>where</u>:

CRDTAV = credit available--thousands £/year

PEQCR = proportion of equity which can be used as a credit base

CRDT = agricultural sector credits--thousands £/year

TDCTS = total demand for credit in the South--thousands £/year

k = indexes the crop sectors--k = 1-4.

If available credit is not sufficient to meet the investment demands, a constraint is placed on the land allocation decisions (Equation (L12)). The constraint is computed by Equation (C12) and averaged over the time of a decision cycle (DTX).

$$\text{(C12)} \quad CNSINU_k(t+DT) = \min\left[\frac{CRDTAV_k(t) + SAGDII_k(t)}{ECAPRT_k(t)}, 1.\right]$$

$$CNSIN_k(t+DT) = CNSIN_k(t) + \frac{DT}{DTX}*[CNSINU_k(t+DT) - CNSIN_k(t)]$$

where:

CNSINU = consumption constraint on agricultural investment--dimensionless

CNSIN = averaged constraint--dimensionless

k = indexes the crop sectors--k = 1-4.

In a similar manner to Equations (C8) and (C9), the disposable income for consumption generated by agricultural processing (by commodity) is computed by Equation (C13). A proportion of processing investment is assumed to be financed from outside the processing sector. A portion of this is included as agricultural sector income in Equation (C6).

$$\text{(C13)} \quad PCDS_i(t) = \max[PCDSR_i*PCDBT_i(t-DT), 0.]$$

$$PCINT_i(t) = PRI*PCDBT_i(t-DT)$$

$$PCDBT_i(t) = PCDBT_i(t-DT) + DT*[PICT_i*PINVT_i(t) + PICM_i*PINVM_i(t) - PCDS_i(t)]$$

$$CAPDI_i(t) = PINC_i(t) - PTAX_i(t) - (1 - PICT_i)*PINVT_i(t) - (1 - PICM_i)*PINVM_i(t)$$

$$- PCDS_i(t) - PCINT_i(t) - OPCT_i(t) - OPCM_i(t)$$

$$CAPDIA_i(t) = PAG_i(t)*CAPDI_i(t)$$

$$CAPDIN_i(t) = (1 - PAG_i(t))*CAPDI_i(t)$$

where:

PCDS = the debt service for the agricultural processing sector--thousands £/year

PCDSR = repayment rate for agricultural processing loans--proportion of debt

PCINT = interest payments--thousands £/year

PRI = interest rate on agricultural processing loans--proportion/year

PCDBT = agricultural processing debt--thousands £

PICT, PICM = proportion of traditional and modern processing investment, respectively, financed by credits from outside the processing sector

PINVT, PINVM = traditional and modern investment in agricultural processing, respectively (Equation (A18))--thousands £/year

CAPDI = disposable income from agricultural processing--thousands £/year

PINC = gross income to agricultural processing (Equation (A31))--thousands £/year

PTAX = processing taxes (Equation (A32))--thousands £/year

OPCT, OPCM = traditional and modern processing operating costs, respectively (Equation (A31))--thousands £/year

PAG = proportion of agricultural processing done by the agricultural producers themselves

CAPDIA = disposable income from agricultural processing which goes to the agricultural sector accounts--thousands £/year

CAPDIN = disposable income from agricultural processing which goes to the nonagricultural sector accounts--thousands £/year

i = indexes the commodities processed--i = 1-3.

Finally, component CRTMBA computes the disposable income for consumption generated by the marketing sector. As before, wages paid are included as income to the sector.

$$\text{(C14)} \quad TAGDIM_2(t) = TMOVHD_2(t) + \sum_{i=1}^{5} (PRFTM_i(t) + WMKT_i(t))$$

<u>where</u>:

$TAGDIM_2$ = disposable income in the agricultural marketing sector in the South--thousands £/year

$TMOVHD_2$ = southern marketing board overhead costs (Equation C3), above)--thousands £/year

PRFTM = marketing profits (Equation (A28))--thousands £/year

WMKT = wages paid in the marketing sector (Equation (A28))--thousands £/year

i = indexes the commodities marketed--i = 1-5.

CHAPTER V : APPENDIX C
Data Tables

THIS APPENDIX PRESENTS tables of selected data values used in the Southern annuals/perennials model. Data are categorized as system parameters, technological coefficients and initial conditions. When not shown here, units on these variables will be found in the referenced equation in Appendix V.B.

TABLE 5.C.1.a. System Parameters:
Profitability Response Parameters for Traditional Perennials.

Variables (Eqn. No.)	Present Uses	Alternative Uses		
		improvement	replanting	new planting other perennial
THRT (L11) (response threshold)	Cocoa	.2	.4	--
	Palm (Palm Sector)	.2	.4	--
	Rubber	.2	.4	.6
	Palm (Rubber Sector)	.2	.4	.6
SHPT (L11) (governs response rate)	Cocoa	1.1	1.	--
	Palm (Palm Sector)	1.1	1.	--
	Rubber	1.1	1.	.9
	Palm (Rubber Sector)	1.1	1.	.9
DRT (L5) (discount rate)	.03	.04	.06	.07

1/ Sources for values of these parameters, unless otherwise indicated, are educated and intuitive guesstimates, as explained in the text.

TABLE 5.C.1.b. System Parameters: Profitability Response Parameters for Annuals and Bush.

Present Uses	Variables (Eqn. No.)[a]	Alternative Uses			
		Traditional perennials	Modern perennials	Food	Tobacco
Bush	DRB (L5)	.06	.07	.05	.05
	SHPB (L11)	.9	.9	.032	1.
	THRB (L11)	.3	.5	.2	.2
		Modern food	Modern perennials	Tobacco	
Food	DRF (L5)	.04	.07	.05	
	SHPF (L11)	1.1	.8	1.	
	THRF (L11)	.2	.4	.2	
		Food			
Tobacco	DRCAF (L5)	.04			
	SHPCA (L11)	1.			
	THRCA (L11)	.2			

a/ Variables are defined by prefixes:
DR_ = discount rates
SHP_ = governs response rates
THR_ = response thresholds

TABLE 5.C.1.c. System Parameters: Diffusion Parameters.

Present Uses	Variables (Eqn. No.)	Alternative Uses				
Bush	CIUDB (L8)	Crop* Sector	Traditional perennial	Modern perennial	Food	Tobacco
		1 2 3 4	.001 .001 .004/.001 --	.02 .02 .02/.02 --	.002 .002 .002 .002	-- -- -- .001
Food	CIUDF (L8)	Crop Sector	Modern food	Modern perennial	Tobacco	
		1 2 3 4	.001 .001 .001 .001	.01 .01 .01/.01 --	-- -- -- .01	
Traditional Perennials	CIUDT (L8)	Present Use	Improvement	Replanting	Other modern perennial	
		Cocoa Palm (Sector 2) Rubber Palm (Sector 3)	.05 .05 .05 .05	.01 .01 .01 .01	-- -- .005 .005	
Tobacco	CIUDC (L8)	Crop Sector	Food			
		4	.001			

*Crop Sectors: 1 = Cocoa-Food Sector; 2 = Palm-Food Sector; 3 = Rubber-Palm-Food Sector; 4 = Food-Cash Annual Sector

TABLE 5.C.1.d.
Production Parameters.

Variable (Eqn. No.)	Commodity				
	Cocoa	Palm	Rubber	Food	Tobacco
PLOSS (A10) (marketing loss factor)	.8	.95	.95	.95	.8
POMC (A11) (proportion consumed)	0.	0.	0.	1.	0.
POMP (A11) (proportion processed)	0.	1.	1.	0.	1.
POMX (A11) (proportion exported)	1.	0.	0.	0.	0.
SUPRSP (A6) (perennials supply elasticity (harvest))	.05	.3	.6	1.5	0.
PROP1T (A21) (proportion of raw material processed as the first output)	--	.75	1.	--	1.
PNFL (A29) (proportion of non-family labor used in production)	.05	.02	.05	.01	.05
PPNFLT (A31) (proportion of non-family labor used in processing)	--	.2	.25	--	.5

**TABLE 5.C.2.a. Technological Coefficients:
Perennial Yields (Pounds/Acre-Year).**

Variable (Eqn. No.)	Perennial Stream (substream)	Production Cohort					
		Rising Yields			Maximum Yields	Declining Yields	Old Age
		1	2	3			
YPER1 (A5)	1. traditional cocoa (trad.)	100	250	300	350	300	250
	2. mod. cocoa (replanted)	200	400	700	800	650	500
	3. trad. palm (Palm Sector) (trad.)	1000	2300	3600	4500	2300	1900
	4. mod. palm (Palm Sector) (replanted)	1500	3400	5500	6700	3400	2400
	5. trad. rubber (trad.)	100	250	350	400	350	350
	6. mod. rubber (replanted)	400	650	800	850	800	800
	7. trad. palm (Rubber Sec.) (trad.)	1000	2300	3600	4500	2300	1400
	8. mod. palm (Rubber Sec.)	1500	3400	5500	6700	3400	2900
YPER2 (A5)	1. trad. cocoa (improved	200	400	500	600	50C	400
	2. mod. cocoa (new planted)	250	500	750	900	800	650
	3. trad. palm (Palm Sector) (improved)	1250	2800	4500	5600	2800	2400
	4. mod. palm (Palm Sector) (new planted)	1500	3400	5500	6700	3400	2900
	5. trad. rubber (improved)	200	350	450	500	450	450
	6. mod. rubber (new planted)	400	650	800	850	800	800
	7. trad. palm (Rubber Sec.) (improved)	1250	2800	4500	5600	2800	2400
	8. mod. palm (Rubber Sec.) (new planted)	1500	3400	5500	6700	3400	2900

Sources: [FAO, 1966], [MANR, Western State, 1969a], [MANR, Western State, 1969b], [Phillips, 1964].

TABLE 5.C.2.b. Technological Coefficients: Input Requirements for Perennials.

Variable (Eqn. No.) (Units)	Perennial Stream[a]	Production Cohorts: Gestation	Rising Yields	Maximum Yields	Declining Yields	Old Age
PLA1[b]	1	25	10	12	12	6
(A25)	2	80	24	20	20	22
(man-days/	3	8	6	4	4	2
acre-year)	4	40	12	10	10	12
	5	12	8	6	6	4
	6	30	16	12	12	14
	7	8	6	4	4	2
	8	40	12	10	10	12
PLA2[b]	1	40	20	18	18	20
(A25)	2	60	22	20	20	22
(man-days/	3	20	10	8	8	10
acre-year)	4	40	12	10	10	12
	5	20	12	8	8	10
	6	30	16	12	12	14
	7	20	10	8	8	10
	8	40	12	10	10	12
PCA1[c]	1	0	0	0	0	0
(A26)	2	165	10.4	16.3	16.3	16.3
(lbs./acre-year)	3	0	0	0	0	0
	4	140	132	132	132	132
	5	0	0	0	0	0
	6	294	300	120	0	0
	7	0	0	0	0	0
	8	140	132	132	132	132
PCA2[c]	1	.0730	10.4	16.3	16.3	16.3
(A26)	2	.0730	210	296	296	296
(lbs./acre-year)	3	0	0	0	0	0
	4	140	132	132	132	132
	5	0	0	0	0	0
	6	217	0	0	0	0
	7	0	0	0	0	0
	8	140	132	132	132	132

Variable	Commodity	Value
PLY[d] (A25)	Cocoa	.0235 man-days/lb.
	Palm	.0015 man-days/lb.
	Rubber	.0275 man-days/lb.

a/ Definitions of the perennial population streams are given in Table 5.C.a above.
b/ Does not include harvesting labor.
c/ Composite of recommended sprays, fertilizers, etc.
d/ Harvesting labor only.

Sources: [FAO, 1966], [MANR, West, 1965], [MANR, West, 1969a], [MANR, West, 1969b], [MANR, Midwest, 1970].

TABLE 5.C.2.c. Technological Coefficients: Mean Length of Perennial Production Cohorts (Years).

Variable (Eqn. No.)	Perennial Stream[a/]	Production Cohorts[a/]				
		1	2	3	4	5[b/]
DFL (L1)	1	6	7	14	13	--
	2	3	7	20	10	--
	3	6	6	20	8	--
	4	3	5	20	12	--
	5	8	4	25	3	--
	6	6	6	20	8	--
	7	6	6	20	8	--
	8	3	5	20	12	--

a/ See the preceeding tables for definitions of the perennial population streams and the production cohorts.
b/ Trees remain in the old age stage indefinitely--see the description of component LAMDAP in the text.

Sources: [FAO, 1966], [MANR, West, 1969a], [MANR, West, 1969b].

TABLE 5.C.3.b. Initial Conditions (1953): Subsistence Levels (Proportion).

	Crop Sector[a/]			
	1	2	3	4[b/]
SUBLEV (A3)	.8	.9	.9	1.

a/ See Table 5.C.1.c for definitions of the crop sectors.
b/ Sector 4 is assumed to always have total subsistence.

Source: Initial guesstimates.

TABLE 5.C.3.a. Initial Conditions (1953): Land Usage (1000 Acres)

Variable (Eqn. No.)	Perennial Stream[a/]	Production Cohorts[a/]					Total
		1	2	3	4	5	
TLPER (L1)	1	125	175	425	200	100	1025
	2	0	0	0	0	0	0
	3	280	280	1120	280	840	2800
	4	0	0	0	0	0	0
	5	115	60	170	25	10	380
	6	0	0	0	0	0	0
	7	90	90	360	90	270	900
	8	C	0	0	0	0	0
	Crop Sector[a/]:	1	2	3	4		
TLBSH (L3)		5300	2500	1500	5000		

a/ Definitions of perennial population streams, production cohorts and crop sectors are in the preceeding tables.

Sources: [FAO, 1966], [Thodey, 1969].

CHAPTER VI
Population Model

THE PURPOSE OF THE POPULATION MODEL is to simulate the growth of the population in each region over the years spanned by a simulation run. In terms of its interaction with the agricultural simulation model, the population model determines the demand for subsistence calories from the agricultural population in each crop area of each region and the demand for food staples purchased through the cash market by the nonagricultural population. The population model also determines the supply of agricultural labor available to work in each crop area in each region, the total population in the agricultural sector in each region, the total population in the nonagricultural sector in each region and the number and growth rate of the farmers in each crop area in each region. The outputs from the population component as well as its inputs are summarized in Figure 6.1.

Population Structure and Dynamics

The population of Nigeria is divided along four dimensions into 324 cells or cohorts. These four dimensions are as follows: region (North and South); occupation (agriculture, nonagriculture and the unoccupied residual); sex (male and female), and age group (27 three-year age groups). This division of the population into cohorts is illustrated in Figure 6.2.

Because the population is divided into three-year age groups, the model does a major update on the population levels in each age-sex cohort once every three years. The first step in this update process is to compute the number of births during the past three years as a function of the number of females in

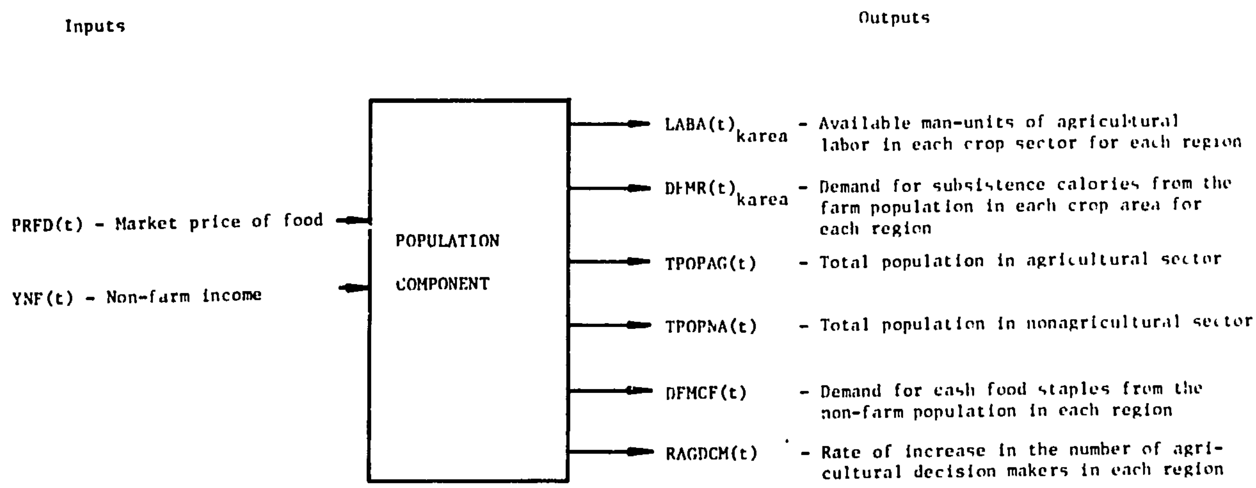


Figure 6.1. Population component: input and output variables for each region.

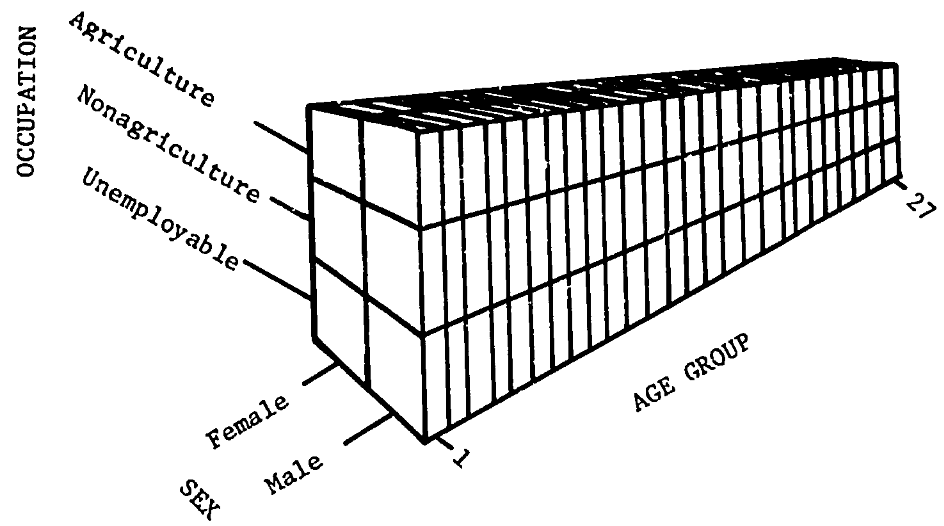


Figure 6.2. Diagram of the population cohorts divided along the dimensions of age, sex, and occupation for each region.

each of the child-bearing age cohorts and the age-specific fertility rates for these cohorts. Thus, the number of infants who enter the first age cohort for the next three-year period is equal to the number of infants born alive, minus those who die shortly after birth.

The remaining age cohorts are updated in much the same way. The persons in a given age-sex cohort, minus the persons who have died during the past three years, are shifted into the next older age group. Deaths in each age-sex cohort during a three-year period are a function of the age-sex-specific death rates for each region.

Every three years the model updates the population cohorts in the manner outlined above. At each update, the values of the various output variables are calculated for two points in time--the beginning and the end of the next three-year time period. These two values are used to calculate a rate of change of the particular variable over the time period. Thus, using the starting value and the rate of change, the population model calculates an interpolated value for the population output variables needed at each increment of time (currently 0.25 year) for which computations are made in the other components of the model during the three-year period of the population update cycle.

Output Variables

As indicated above, the population model outputs several "system-level" variables utilized by the other components of the agricultural simulation model.

The population model supplies man-units of agricultural labor for each crop area in the two regions. This available supply of labor is calculated as a product of four factors: (1) the proportion of each age-sex cohort employed in the total labor force; (2) the proportion of the total labor force in each age-sex cohort employed in agriculture; (3) an equivalent time factor for each age-sex cohort, and (4) an equivalent physical energy factor for each age-sex cohort. The last two factors take into account the fact that different persons, depending on their sex and age, have different amounts of time and physical energy to devote to agricultural labor. For example, children, women and older persons contribute fewer effective man-units of labor than a reference man between the ages of 21 and 40 because different amounts of time are allocated to agricultural work and different physical abilities are associated with each age and sex. This available supply of labor is then distributed to each crop area in each region. In order to take into account a shift of labor from the agricultural sector to the nonagricultural sector, the proportion of the labor force employed in agriculture is reduced by an externally specified amount each year of the simulation run. In later versions of the population model, it is planned to make the rural-urban migration rate a function of other internal variables, such as rural-urban wage rate differentials.

In order to determine the demand for subsistence calories from the agricultural sector, as well as the demand for food staples flowing through the cash market in the nonagricultural sector, it is necessary to divide the population into a farm population and a nonfarm population. This is a slightly different distinction from a division of the population into rural and urban. Demographers tend to divide a population into rural and urban on the basis of the size of the community in which people live. People living in communities smaller than a specified size are considered to be part of the rural population. However, for the population model the distinction is made between people who live on farms and grow at least part of their own food, and people who do not live on farms and must therefore purchase all of their food staples through the cash food market. The division into a farm and nonfarm population is proportional to the number of males employed in agriculture and the number of males employed in nonagricultural occupations.

The net demand for subsistence calories, then, is simply the total farm population times the average calories consumed per person. This demand for subsistence calories is distributed among the crop areas in each region proportionally to the distribution of the labor force in these areas.

The total demand for food staples purchased in the cash market by the nonfarm population in each region is a function of the total nonfarm population, the average price per pound of food staples and the average per capita income in the nonagricultural sector. In the southern region, the farm population also purchases some of its food through the cash food market.

The number of agricultural decision makers in each region is taken to be the number of males over 30 years of age employed in agriculture. It is likely that there are some males under 30 who are decision makers and some males over 30 who are not decision makers, but 30 is probably a good average dividing point. The rate of increase in the number of agricultural decision makers is an output variable which affects the rate at which new land comes into production simply as a result of the increase in farm population.

Data

The first group of variables and parameters which had to be estimated for processing the population model was the set of basic demographic variables: the age-sex distribution, the age-specific birth and death rates, sex ratio at birth and the rate of decline in the death rates. In the current version of the model, birthrates are assumed to remain relatively constant. A later version will allow for a decline in birthrates over time in order to simulate the effects of population control measures. Most test runs of the simulation model started in the early 1950's because time-series data on the output of various agricultural crops were available for the period from 1953-65. The best available source of demographic data on Nigeria for that time was the 1953 Census of Nigeria. However, this census did not directly satisfy the data needs of the population model for three reasons. First, the age distribution breakdown in 0-1, 2-6, 7-14, 15-49 and 50-plus age groups showed a disproportionate number of people in the large 15-49 age group, probably as a result of the problem census takers had in determining actual ages for persons near the limits of this age group. These broad age groupings of the census and the biased distribution made it difficult to construct an adequate age distribution of the Nigerian population in terms of the 27 three-year age groupings utilized in the model. Second, there is general agreement among demographers that the census was under-reported by at least 10 percent. In fact, the discrepancy between the 1953 Census and the 1963 Census tallies indicated that the 1953 Census could have been off by as much as 30 to 35 percent, depending on which set of figures one believes. The 1963 Census figures have been criticized by demographers for being inflated in each region for political reasons.1/ Finally, neither the 1953 Census nor 1963 Census provide data on age-specific birth and death rates. For these reasons, a published analysis of demographic data for neighboring Dahomey was used as a guide in arriving at a reasonable set of vital statistics for Nigeria.2/

The age-sex distribution curves for Nigeria in 1953 were estimated by distributing the total population of Nigeria according to the age-sex distributions found in Dahomey in 1961. Subsequent test runs with the population model indicated that the percentage distribution of the population did not change appreciably over a 30-year period if one assumed fairly constant birthrates and only slightly declining death rates. Also, percentage distributions across age groups appear to be fairly similar for different African populations (Brass, 1968). Thus, it appears it was not a bad approximation to use the 1961 distribution of the population in Dahomey to estimate the 1953 distribution of the population in Nigeria across age-sex cohorts.

Initial test runs with the population were conducted, assuming that the 1953 Census was under-reported by 10 percent. Later runs of the simulation model were made, assuming that the 1963 Census was approximately correct in its total tally. Thus, the population data used in the model were brought into line with the population figures used in planning projections for the 1970 Five-Year Plan.

1/ For a summary of the discussion among demographers concerning the Nigerian censuses, see Ferguson, 1967.

2/ See "Fertility in Nigeria" by E. van de Walle and "The Demography of French-Speaking Territories Covered by Special Sample Inquiries: Upper Volta, Dahomey, Guinea, North Cameroon, and Other Areas" by W. Brass in Brass, *et al.*, 1968. The Dahomey data were collected by a 1/18 sample survey conducted in 1961.

A sensitivity analysis indicated that the behavior of the total simulation was not appreciably affected by the choice of population figures.

Age-specific death rates for the northern region were also derived from death rates for Dahomey, although they were reduced to yield a crude death rate of about 26 per thousand instead of 33 per thousand as found in Dahomey. This was done to yield an overall growth rate of 2.0 to 2.5 percent which has been estimated for Nigeria by Okonjo (see Caldwell, 1968), Ferguson (Ferguson, 1967) and others. Furthermore, in light of the probably more advanced state of development of Nigeria, even in 1953, over that of Dahomey in 1961, a lower death rate is justified. The decline in death rates for the period of the simulation runs was arbitrarily estimated to be 1.7 percent per year and the decline in infant mortality rates to be about 1 percent per year.

Age-specific birthrates, which were assumed to remain constant throughout the simulation run, were based on birthrates for Dahomey which had been estimated by an analysis of survey data on births during the previous year to women of child-bearing age. Birthrates were increased 12.5 percent to raise the rate of natural increase to produce enough births to maintain a smooth age-sex distribution curve over a nine-year trial simulation period for Nigeria.

In an early simulation run using these adjusted figures from Dahomey and the 1953 Census totals adjusted upward by 10 percent, the Nigerian population grew from 34,233,000 in 1953 to 43,635,000 in 1962 at an annual rate of 2.4 percent in the North and 2.7 percent in the South. This figure for the 1962 population is close to the estimates of Okonjo, Ferguson and others. In later runs based on the 1963 Census figures, the population grew from 45,547,000 in 1953 to 53,256,000 in 1961 at an annual rate of 2.0 percent in the North and 2.2 percent in the South.

The second group of parameters to be estimated included those dealing with the labor force. The age-sex-specific distribution of the proportion of people in each cohort working in the labor force and the proportion of the labor force in each cohort working in agriculture, were determined by an analysis of both the 1953 Census and the 1963 Census. However, according to data gathered in the 1967 Labor Survey and published in the 1970 Five-Year Plan, these figures indicated too high a percentage of males in the labor force (58 percent), too low a percentage of females (22 percent) and too low an overall percentage of labor employed in agriculture (60 percent in 1953). These percentages were revised to be more in line with the following data published from the 1967 Labor Survey: 43 percent of the males and 36 percent of the females were employed in the labor force; 78 percent of the 15-55 year age group were employed in the labor force; 80 percent of the males in the labor force, and 62 percent of the females were employed in agriculture in 1967.

Rather arbitrary estimates were made for the proportion of time worked by laborers in each cohort compared to the time worked by a reference man between the ages of 18 and 45, and the amount of physical energy expended compared to the energy expended by a reference man between 21 and 39. For example, it was assumed that a 30-year old woman in the labor force would be able to devote approximately 80 percent as much time to her work as a man between the ages of 18 and 45 and that she would expend about 87.5 percent of the physical energy expended by a man between the ages of 21 and 39.

The geographical distribution of labor across the crop areas was based on data reported in the 1953 Census and the 1963 Census. Migration from the agricultural sector to the nonagricultural sector was arbitrarily estimated to be 0.750 percent per year for men and 0.500 percent per year for women in the North and 2.0 percent for men and 1.0 percent for women in the South.

The third group of parameters included those required for the food demand equations. The elasticities used in the cash-food demand equation were estimated by means of a regression analysis of data reported from urban consumer surveys conducted in seven urban areas between 1959 and 1966 and from food price data reported in the Annual Abstract of Statistics, Nigeria, 1966. The income elasticity for food staples was found to be 0.33 and the price elasticity was found to be -0.96. However, there were problems with this analysis because of the way the data was reported and the small number of cases (20). The absolute value of the price elasticity seemed unrealistically high. During the process of tuning the model, the value for the price elasticity was changed to -0.30. The constant term in the demand equation, ELASFC, was adjusted to make the quantity demanded consistent with the population level, the food price index and the income levels utilized in the simulation model. The daily subsistence requirement for food staples, CALPP, was estimated to be about 1,900 calories per person per day. This figure was based on the age distribution of the population and on data published by the Food and Nutrition Board of the U. S. National Academy of Sciences in 1968.

Summary

The population model is one component of the overall agricultural simulation model for Nigeria. Its main function is to simulate the growth of the population in order to output a supply of available labor and a total demand for food staples. These output variables become inputs into other components of the model.

However, the model is also completely general. It may be run separately under its own executive program in order to simulate the population growth in any country or region. One use of the model is to check on the internal consistency of the vital population statistics which might be derived from different sources for a particular country. This was done in the case of Nigeria. Adjustments were made in birth and death rates obtained from data on Dahomey in order to make the population distribution across age groups remain fairly stable over time.

CHAPTER VI : APPENDIX

The Population Model

Population Structure

THE INITIAL DATA ARRAYS entered into the computer program distribute the population along three dimensions: region, age and sex. Two additional arrays, TLF and AGR, are used to distribute the population into the three different occupational categories: agriculture, nonagriculture and residual. The number of people in the agricultural labor force in each age-sex cohort in each region is given by:[1/]

(POP1) $POP(t)_{kage,jsex,agric} = POP(t)_{kage,jsex}*TLF_{kage,jsex}*AGR(t)_{kage,jsex}$

where:

$POP_{kage,jsex,agric}$ = the number of persons in the agricultural labor force in a given age-sex cohort

$POP_{kage,jsex}$ = the total number of persons in a given age-sex cohort

$TLF_{kage,jsex}$ = the fraction of persons in a given age-sex cohort in the labor force (an externally defined model parameter)

$AGR_{kage,jsex}$ = proportion of the labor force in agriculture in a given age-sex cohort (see Equation (POP16)).

The number in nonagricultural occupations is given by:

(POP2) $POP(t)_{kage,jsex,nonag} = POP(t)_{kage,jsex}*TLF_{kage,jsex} - POP(t)_{kage,jsex,ag}$

The residual population outside the labor force in each region, mostly children and older persons, is:

(POP3) $POP(t)_{kage,jsex,resid} = POP(t)_{kage,jsex} - POP(t)_{kage,jsex,agric} - POP_{kage,jsex,nonag}$

Output Variables

The number of equivalent man-units of labor in the agricultural sector in each region at a given time, t, is:

(POP4) $AGMU(t) = \sum_{kage=1}^{27} \sum_{jsex=1}^{2} EQVDAY_{kage,jsex}*EQVMAN_{kage,jsex}*POP(t)_{kage,jsex,agric}$

1/ In all of the following equations, the index specifying the region is deleted from the variables in order to simplify the subscripting. The units on all variables are expressed in thousands.

where:

AGMU = man-units of labor in the agricultural sector in each region at time t

$EQVDAY_{kage,jsex}$ = proportion of a reference man-day worked by a laborer in an age-sex cohort

$EQVMAN_{kage,jsex}$ = proportion of a reference man's physical energy expended by a laborer in an age-sex cohort.

As stated in the body of the chapter, the above relationship takes into account the fact that different persons, depending on their sex and age, have different amounts of time (EQVDAY) and physical energy (EQVMAN) to devote to agricultural labor. The man-units of labor in the agricultural sector are distributed among the four crop areas of each region as follows:

(POP5) $LABA_{karea}(t) = DLABOR_{karea}*AGMU(t)$

where:

$LABA_{karea}$ = available man-units of agricultural labor in each of the crop areas in each region

$DLABOR_{karea}$ = proportion of the total agricultural labor force located in each of the crop areas, assuming uniform age-sex distribution and no inter-area migrations.

The available labor in each crop area of each region is an output from the population component.

The division of the total population in each region into a total population in agriculture and a total population in nonagriculture, including dependents from the residual occupational category defined in Equation (POP3), is made on the basis of the number of males in the agricultural labor force and the number of males in the nonagricultural labor force.

(POP6) $TPOPAG(t) = TPOPR(t)*[TOTOCC(t)_{male,agric}/(TOTOCC(t)_{male,agric} + TOTOCC(t)_{male,nonag})]$

where:

TPOPAG = total agricultural population including dependents in each region

TPOPR = total population in each region

$TOTOCC_{male,agric}$ = total number of males in the agricultural labor force in each region

$TOTOCC_{male,nonag}$ = total number of males in the nonagricultural labor force in each region.

The remaining population (the nonagricultural sector) of each region is given by:

(POP7) TPOPNA(t) = TPOPR(t) - TPOPAG(t)

where:

TPOPNA = total nonagricultural population including dependents in each region.

The demand for subsistence calories from the agricultural population in each crop area in each region is considered to be proportional to the distribution of the labor force across each of the areas.

(POP8) $DEMR(t)_{karea} = DLABOR_{karea,agric} * TPOPAG(t) * CALPP$

where:

$DEMR_{karea}$ = demand rate for subsistence calories per year from the agricultural population in each crop area in each region

CALPP = average per capita calories required per year (an externally defined parameter)

$DLABOR_{karea,agric}$ = proportion of the total agricultural labor force located in each of the crop areas in each region, assuming the agricultural population and farm population have the same distribution among crop areas.

DEMR is an output variable from the population component.

The demand for cash food (staples) from the total nonagricultural population in each region is a function of the total nonfarm population, the average price per pound of food staples and the average per capita income in the nonagricultural sector.

(POP9) $DEMCF(t) = TPOPNA(t) * ELASFC * [PRFD(t)]^{ELASFP} * [YNF(t)/TPOPNA(t)]^{ELASFY}$

where:

DEMCF = demand for food staples in each region, calories/year

ELASFC = empirical constant

ELASFP = empirically determined price elasticity

PRFD = average price of food staples in each region, £/pound

ELASFY = empirically determined income elasticity

YNF = total income earned by the nonfarm population in each region, £/year.

DEMCF is an output variable from the population component.

Population Dynamics

The updating mechanism for the population component operates on two different cycles: a major cycle DTY of three years and a minor cycle DT equal to the time increment utilized by the rest of the model (currently 0.25 years). The reason for having a major cycle of three years in the population component is that the population is divided into 27 age groups of three years each. Thus, the population may be shifted between the age cohorts only once every three years.

In the current version of the population component, the birthrates for each region, $BIRTHR_{kage}$, are assumed to remain constant during the duration of the simulation, i.e., it is assumed that there is no effective birth control program and that the country has not yet entered the period in which birthrates begin to fall naturally. On the other hand, the death rates for each region, $DEATHR_{kage,jsex}$, and the infant mortality rate for each region, INMOR, are assumed to be declining during the duration of a simulation run as a result of the introduction of improved health practices. The decline in the infant mortality rate is computed as:2/

(POP10) $INMOR(tm) = INMOR(tm-DTY)*(1.0 - DECINM)^{DTY}$

where:

tm = average time during major cycle time period, t + (DTY/2)

INMOR = average infant mortality rate during the major cycle of DTY years in each region

DECINM = fractional decline per year in the infant mortality rate in each region

DTY = major cycle of three years.

The decline in death rates is computed as follows:

(POP11) $DEATHR(tm)_{kage,jsex} = DEATHR(tm-DTY)_{kage,jsex}*(1.0 - DECDTH)^{DTY}$

where:

$DEATHR_{kage,jsex}$ = age-sex-specific death rates in each region

DECDTH = fractional decline per year in the age-sex-specific death rates in each region.

The next step in the population updating mechanism is to delete the decedents from each age-sex cohort and shift the remaining population into the next older age-sex cohort.

(POP12) $POP(t+DTY)_{kage,jsex} = POP(t)_{kage-1,jsex}*[1.0 - DEATH(tm)_{kage-1,jsex}]^{DTY}$

2/ The death rates calculated in Equations (POP10) and (POP11) will decline asymptotically to zero. A better formulation would include a nonzero asymptote. However, the equations as they stand are good approximations over the 40-year duration of most simulation runs.

The number of males who enter the youngest age cohort is a function of the total number of births, the infant mortality rate and the sex ratio at birth.

(POP13) $POP(t+DTY)_{kage=1,male} = TBIRTH(tm)*(1.0 - INMOR(tm))*[SRATIO/(1.0 + SRATIO)]$

where:

TBIRTH = total number of births during the major time cycle (see Equation (POP15)) in each region

SRATIO = the number of males born per female born.

The number of females who enter the youngest age cohort is given by:

(POP14) $POP(t+DTY)_{kage=1,female} = TBIRTH(tm)*(1.0 - INMOR(tm))*[1.0/(1.0 + SRATIO)]$

The total number of births during a major time cycle is:

(POP15) $$TBIRTH(tm) = \sum_{kage=1}^{27} POP(t)_{kage,female}*BIRTH(tm)_{kage}*DTY$$

In order to take into account migration from the agricultural sector to the nonagricultural sector, the proportion of the labor force working in agriculture, AGR(t), is reduced over the time of each major cycle, DTY, according to Equation (POP16).

(POP16) $AGR(t+DTY)_{kage,jsex} = AGR(t)_{kage,jsex}*[1.0 - RUM_{jsex}]^{DTY}$

where:

RUM_{jsex} = "rural-urban" migration rate for each region (an externally defined model parameter).

This value of AGR is used in Equation (POP1) to compute the agricultural and nonagricultural labor force. Since RUM is an externally defined model parameter which does not change over time, the model currently does not account for the effects on rural-urban migration of changes in urban unemployment or rural-urban income differentials.

Although Equations (POP4), (POP6) and (POP7) are correct conceptually, the actual computational procedure of the simulation model only uses these equations to compute the number of man-units of labor employed in the agricultural sector, AGMU(t), the total farm population, TPOPAG(t), and the total nonfarm population, TPOPNA(t), at the beginning and at the end of each major cycle. These two values for each variable are then used to calculate a rate of change of that variable which holds during a major cycle.

(POP17) $RAGMU(tm) = [AGMU(t+DTY) - AGMU(t)]/DTY$

(POP18) $RTPAG(tm) = [TPOPAG(t+DTY) - TPOPAG(t)]/DTY$

(POP19) $RTPNA(tm) = [TPOPNA(t+DTY) - TPOPNA(t)]/DTY$

<u>where</u>:

RAGMU = rate of change of man-units of agricultural labor in each region during major time cycle, tm

RTPAG = rate of change of the total farm population in each region during major time cycle, tm

RTPNA = rate of change of the total nonfarm population in each region during major time cycle, tm.

Thus, the values of AGMU(t), TPOPAG(t) and TPOPNA(t) as used in Equations (POP5), (POP8) and (POP9) are computed each time increment, DT, by the following equations:

(POP20) AGMU(t) = AGMU(t-DT) + RAGMU(tm)*DT

(POP21) TPOPAG(t) = TPOPAG(t-DT) + RTPAG(tm)*DT

(POP22) TPOPNA(t) = TPOPNA(t-DT) + RTPNA(tm)*DT

<u>where</u>:

DT = the time increment used in the overall simulation model.

CHAPTER VII

A Supplementary Model of the National Economy for Agricultural Sector Analysis

IN THE INITIAL BUILDING AND TESTING of the simulation models of the agricultural sector, only parameters of the agricultural sector were considered. However, any effort to model the agricultural sector as a separate entity requires that some parameters of the nonagricultural economy be treated exogenously. This chapter discusses the importance of agricultural-nonagricultural interactions in agricultural sector planning and proposes an elementary model of the total economy which can be used in conjunction with a detailed agricultural sector model for a more complete analysis of the agricultural sector.

Several key interactions between the agricultural and nonagricultural economies are relevant to agricultural sector analysis. In particular, the flows of goods and services between agriculture and nonagriculture are important in developing economies for several reasons:

1. Food often constitutes over half the consumption expenditure of the nonagricultural population, providing the most important market for agricultural output.

2. Since over half the total population is usually in agriculture, the agricultural population is a vital market for expanding the domestic production of nonagricultural goods and services.

3. The initial stages of industrialization often consist of industries utilizing raw materials supplied by agriculture, e.g., cotton for textile manufacturing.

4. Agricultural modernization requires inputs of nonagricultural goods and services, e.g., fertilizers, machinery, again providing a domestic market for nonagricultural output.

In addition, the agricultural and nonagricultural economies interact in the factor markets. Capital and foreign exchange are often scarce resources which must be allocated between agriculture and nonagriculture. Furthermore, the distribution of the labor supply between agriculture and nonagriculture depends on the rate of rural-urban migration, which in turn is affected by the rural-urban income differential.

Recognition of these interactions between the agricultural and nonagricultural economies is important to agricultural sector analysis for two reasons. First, variables of the nonagricultural economy which are inputs into the agricultural economy become endogenous to the system. In a dynamic model, this enables the full implications of agricultural policies for the agricultural economy to be considered after taking account of the various interactions and feedbacks from the nonagricultural economy. Second, the policy maker usually wishes to study the effect of agricultural policies on the national economy. This requires knowledge of the impact of agricultural policies on the nonagricultural economy.

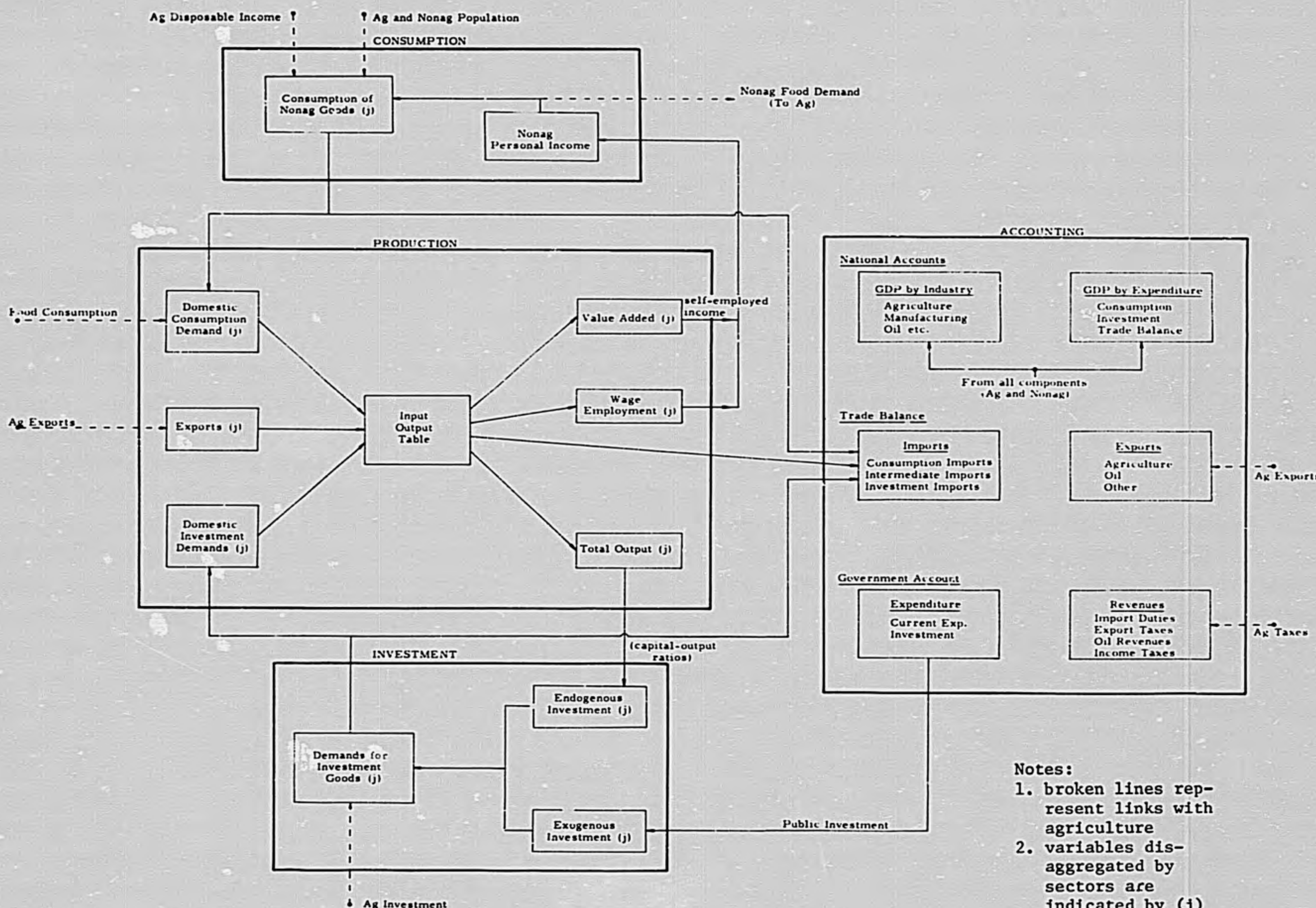
An example of the effects of a policy of increasing agricultural export prices illustrates these points. Assuming that an increase in prices results in an increase in the production of export crops, both the demand for nonagricultural goods and services for production and consumption will be increased. Furthermore, the additional foreign exchange may be a stimulus for nonagricultural investment. The resulting increase in nonagricultural income leads to an increased demand for food by the nonagricultural population. This, in turn, leads to repetition of these feedbacks and the generation of second and third round effects. By this interaction with the nonagricultural economy, the original increase in agricultural income produces a multiplier effect in the agricultural economy. The full impact of the policy on the agricultural economy cannot be realized without making agriculture-nonagriculture interactions endogenous to the system. Furthermore, from a national viewpoint, increases in output and employment in the nonagricultural economy must be considered in evaluating such agricultural policies. Again, the need arises for a model of the national economy.

This chapter describes a simulation model of a total economy designed to interact with more detailed sector models. An overview of the model is given in Figure 7.1. It disaggregates the total economy (in this case, Nigerian) into a number of sectors of interest, e.g., manufacturing, agriculture, services, etc., linked by means of an input-output table. At the beginning of each period, consumption and investment are generated endogenously in separate components of the model. In each case, only a few key variables are considered. For example, consumption is assumed to depend only on population and personal income. Exports are supplied exogenously to the model and aggregated with consumption and investment to give total final demands from each sector. Using conventional input-output techniques, these final demands are translated in the production component into inter-industry flows, intermediate imports and value added for each sector. These results are then used in the construction of the national accounts and the computation of consumption and investment in succeeding periods. Various lags and smoothing processes in the model reflect the decision-making behavior of producers and consumers and give stability to the system. For example, consumption is assumed to be a function of an exponentially lagged value of income rather than income in the current period.

The above model is an elementary means of describing the total economy. It is static in the sense that many parameters, particularly the input-output coefficients, are exogenous to the system, although they may be varied exogenously over time to reflect structural changes in the economy. However, the model does go much further than static input-output analysis in making consumption, investment, imports and employment endogenous in the system.

Because of its simplicity, the model has little value in detailed national policy formulation, although it may help in making aggregate economic projections and understanding the interactions between sectors. An example will be given later to show the different linkage effects of comparable increases in agricultural exports and oil exports. The essential point is that, although the model can show the implications of a given increase in agricultural output for the total economy (after the interactions discussed above are considered), it does not show how an increase in agricultural output may be achieved.

The present macro-model has been designed to interact with a detailed agriculture sector model. With only minor modifications, it could also interact with any other sector model such as a model of small-scale industry. This type of interaction enables detailed policy evaluation within a sector as represented in Figure 7.2. In the total model, agriculture is represented by a single sector. However, merging it with the detailed agricultural models enables all the inputs and outputs of the sector to be computed endogenously, taking account of the many ecological regions.



Notes:
1. broken lines represent links with agriculture
2. variables disaggregated by sectors are indicated by (j)

Figure 7.1. The national model.

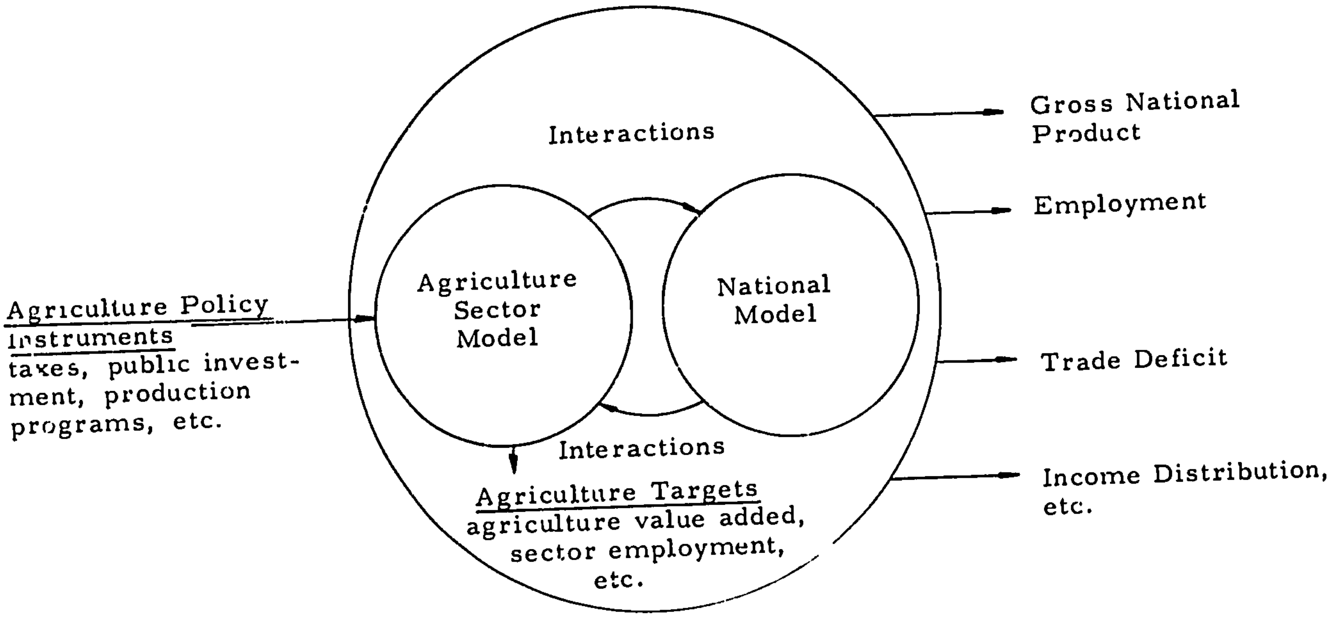


Figure 7.2. The national model in a policy framework.

commodities and other complex interactions of the sector. Thus, agricultural consumption, investment, exports, employment and the relevant input-output coefficients become functions of agricultural policy instruments. In turn, the nonagricultural sectors feed back to the agriculture sector models relevant variables (such as nonagricultural income, which is an element of the demand for food), and these variables become endogenous to the agricultural system. This whole process allows agricultural policy experiments to be evaluated in the context of the total economy.

The various components of the macro-model are described below and a more detailed mathematical description of the model is given in the appendix. Some test runs will be presented to illustrate the usefulness of the model.

Components of the Model

Exports

Exports are regarded as exogenous variables in the model. In the Nigerian case, there are two main groups of exports: agriculture and petroleum. Agricultural exports are either assumed to grow at a rate reflecting recent historical trends or are computed endogenously in the detailed agriculture sector model and fed to the macro-model. In the case of oil, future exports are a function of many uncertainties such as the success of exploration and international oil politics. Thus, optimistic and pessimistic time-series projections were used to represent oil exports.

Consumption

The consumption component simulates the demands by various classes of consumers for domestically produced goods and services and for imports of goods and services. Presently, only agricultural and nonagricultural classes of consumers are considered (approximating the rural and urban populations) although the model has the flexibility to account for different consumption behavior by regions and income levels when data are available.

The total consumption of goods and services of each sector[1/] is a function of the population and personal income of each class of consumers (Equation (C4)). This function takes account of the different consumption levels and behavior of rural and urban populations. The relative prices of goods and services are assumed constant, except where the model interacts with a detailed agriculture sector model. Here the consumption of food by the agricultural and nonagricultural populations may be computed by the interaction of supply and demand, and fed to the aggregative model. The consumption of nonagricultural goods and services is then a function of personal income, population and the price of nonagricultural goods relative to food.

Finally, the demand for goods and services is totaled over all consumers and divided between domestic production and imports. The proportion imported is determined exogenously in the model although this proportion is trended downward over time to reflect import substitution. The demand for domestically produced goods is then fed to the production component.

Investment

Investment in each sector is divided between public investment and private investment. Public investment is modeled as an exogenous variable in the system; this investment tends to be concentrated in the transportation, utilities and service sectors. With the exceptions of agriculture and oil, private investment is endogenously determined, using incremental capital-output ratios for each sector. Inventories and replacement investment are assumed to be a fixed proportion of total gross investment.

Agricultural investment is either an exogenous variable of the system or is computed endogenously in the agricultural sector model. Some agricultural investment such as land clearing and cattle breeding are considered to require negligible intermediate inputs, e.g., machinery or construction. Since this investment does not create any immediate demand for goods and services, it is not added to the investment demands for domestic production but is included in the national accounts.

Investment in the oil industry consists of two types: exploration and production. Since exploration investment (the dominant form of current investment in Nigeria) is a long-run process with highly uncertain outcome, it is impossible to relate investment to output by a capital-output ratio. Hence, investment in the oil industry, though private, is assumed to be exogenously determined.

Finally, investment by households in residential construction generates a substantial source of domestic investment demand. This is computed as a function

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1/ *The term, sector, is used here, as in Chapter V, to refer to production sectors such as agriculture and manufacturing. A fuller discussion of the sectoral breakdown is given in the description of the production component.*

of personal income and population, with a relatively long delay attached to the effect of personal income changes.

These investment demands by each sector must be translated into demands for capital goods from each sector. For example, total investment in the manufacturing sector must be disaggregated into demands for construction, machinery, transport, etc. and imports. A matrix of exogenously specified coefficients, analogous to an input-output table, is used to perform this disaggregation (Equation (I4)). The requirements for domestic production generated by investment are then fed to the production component.

Production

The basis of the production component is an input-output table of the economy. For the case of Nigeria, data collected by Carter (1966) for the year 1959, were used to construct an input-output table of the economy with 10 sectors divided into two groups, traditional and modern. Details of the composition of each of these sectors are given in Table 7.1. There are four small-scale sectors: agriculture, residual agriculture, small industry and small trade-services composed of firms

TABLE 7.1
The Sector Breakdown in the National Model.

Sector	Name	Composition of Sector
1	Agriculture	Main cash crops, food staples, and cattle
2	Residual Agriculture	Residual crops, residual livestock, fishery and forestry
3	Small Manufacturing	Carpentry, weaving, shoe making and other crafts
4	Small-Scale Services	Petty trading and services
5	Mining	Metal and nonmetal mining and petroleum
6	Construction	Residential housing, private and public construction projects
7	Transport	Rail, boat, road, air
8	Utilities	Electricity and water
9	Large Manufacturing	Processed food, drink, tobacco, chemicals, metal manufacturing, etc.
10	Large Services	Large scale trading companies, banking, insurance, etc.

employing less than ten persons. These firms generally use family labor and traditional methods of production. The remaining sectors all employ 10 or more persons and use wage employment. Modern capital-intensive methods of production are common in these sectors. This distinction on the basis of scale of industry is useful in simulating investment, employment and consumption since the small-scale sectors tend to be more labor-instensive and produce commodities with different consumer tastes.

The input-output table employed in the model is shown in Table 7.2. This table illustrates some typical aspects of a developing economy. The traditional small-scale sectors are characterized by limited interaction with the rest of the economy relative to the large-scale sectors. Likewise the large-scale sectors have higher import requirements. However, in a rapidly growing economy such as Nigeria the structure of the economy as represented by an aggregated input-output table is likely to change over time. For example, the period 1959-66 in Nigeria was one of rapid growth in the oil industry. Whereas, in 1959 the mining sector consisted mainly of coal and tin mining, by 1965 petroleum had become the dominant output of this sector, resulting in possible changes in the input-output coefficients of the sector. Without further disaggregation it is not possible to reflect these changes endogenously. Another possible change in input-output coefficients can come about through substitution, particularly import substitution where domestic sources of inputs are

TABLE 7.2
Input-Output Coefficients of the Nigerian Economy for 1959[a].

Production Sectors	Small Scale 1	2	3	4	Large Scale 5	6	7	8	9	10
1. Main Agriculture	.0	.0	.085	.0	.006	.0	.0	.0	.137	.0
2. Residual Agriculture	.0	.0	.068	.0	.0	.092	.0	.037	.025	.0
3. Small Manufacturing	.001	.001	.0	.008	.006	.021	.045	.068	.015	.010
4. Small Trade-Services	.001	.003	.040	.0	.012	.067	.016	.019	.007	.028
5. Mining-Oil	.0	.0	.001	.0	.0	.051	.008	.079	.007	.0
6. Construction	.0	.0	.0	.003	.007	.0	.0	.004	.002	.019
7. Transport	.003	.063	.037	.018	.018	.079	.0	.054	.027	.013
8. Utilities	.0	.005	.002	.0	.020	.001	.0	.0	.014	.007
9. Large Manufacturing	.0	.0	.021	.002	.007	.029	.023	.023	.0	.011
10. Large Services	.004	.003	.037	.023	.012	.010	.028	.018	.037	.0
Imports	.016	.014	.197	.009	.223	.228	.113	.135	.232	.031

a/ Each column shows the input requirements for production of one unit of output. For example, one unit of agricultural output (column 1) requires the input of .001 units of Small Manufacturers and .016 units of imports.

substituted for previously imported materials. Again, making these changes endogenous in the system would require making imports competitive with domestic production (Chenery, 1963).

These processes of building new industries, changing techniques and import substitution are fundamental to the development process. Without making them endogenous in the system, the model can have little value in national policy formulation. However, by reflecting these processes exogenously we are able to describe the growth of the economy and understand the implications of these changes for development.

Given this input-output table, the production component first aggregates the final demands of exports, investment and consumption, and then, by input-output techniques, computes value added, imports and total output of each sector. Total output is fed to the investment component, and value added and imports to the national accounts. Finally, personal income is computed. This consists of wage earnings for the modern sectors and income of the self-employed in the traditional sectors.

Wage employment in each sector is assumed to grow at the same rate as the output of the sector with an adjustment for productivity changes (Equation (P7)). These productivity changes arise from many factors such as the underutilization of the existing capital stock and increasingly capital-intensive techniques of modern production. Rate of change of productivity and wages are assumed to be exogenously determined in the model. Also included in wage employment is government employment, which is related to government value added.

Earnings of the self-employed are assumed to be a proportion of value added, with the remaining proportion being invested or remitted abroad. The proportion of value added accruing to the self-employed is very high for the traditional sectors and lowest for the mining and petroleum sectors.

Wage earnings and self-employed earnings are summed to give personal income, which is fed to the consumption component. Clearly, in these computations of personal income, many factors such as taxes and wage rate determination have been ignored. Again the availability of a detailed sector model enables a much more sophisticated modeling of these variables for that sector.

National Accounts

At the end of each series of computations, the model constructs a set of accounts. The national accounts include estimates of gross domestic product by branch of activity, e.g., agriculture, manufacturing, government, etc., and by category of expenditure (consumption, investment and the trade deficit). This is a simple accounting procedure aggregating results from all components. Similarly, the trade balance is computed as the total of all exports of goods and services less the total of all imports of goods and services, valued at F.O.B. prices. The computation of government revenues such as import duties requires exogenously specifying such policy parameters as tax rates. These accounts form the basis of the output of the model used in evaluating agricultural policies at the macro-economic level.

Data Requirements of the Model

Corresponding to each component of the model is a key set of parameters, the input-output coefficients of the production component, capital-output ratios of the investment component and income elasticities of demand of the consumption component. In each case the degree of disaggregation determines the amount of data required.

Increasingly, input-output tables describing inter-industry flows of goods and services are becoming available in developing countries. These can provide the kind of data required to simply account for some of the major interactions in the economy. Similarly, data for estimating aggregate consumption elasticities will not usually be a limiting factor, although disaggregation by rural and urban populations may not always be possible. Data on capital-output ratios and the determinants of investment probably involve the highest degree of uncertainty, because many factors often affect the relationship between investment and output. In the case of Nigeria, we found a good deal of uncertainty as to actual levels of current investments, which adds to the uncertainty in estimating the capital-output ratios.

In particular, over the period 1959-66 there are four independent and widely divergent estimates of investment for Nigeria (Langley, 1963). Part of the difference in these estimates arises in measurement of investment in agriculture. The official estimates include only investment in plant and equipment while Helleiner (1966), for example, includes the value of land development. In any event, the total investment in agriculture is probably grossly underestimated, leading to understatement of the estimated contribution of agriculture to gross domestic product.

While aggregation of the economy into fewer sectors reduces the data requirements[2/], it also reduces the model's ability to describe the economy. A high degree of aggregation necessarily entails lumping together a number of diverse industries into one sector. In a dynamic economy, each of these industries will be growing at different rates, changing the composition of that sector, and hence, the parameters describing overall sector behavior. The oil industry in Nigeria illustrates a rapidly growing industry which is likely to change the parameters of the mining sector. In the short run, such changes may be modeled exogenously particularly if parameters such as input-output coefficients can be estimated at two or more points in time. Thus, we used the work of Clark (1967) as a guide to the changes in the parameters of the model for Nigeria between 1959 and 1965. In the longer run, such changes can only be modeled with a great deal of uncertainty.

Testing and Running of the Model

The model was tested and tuned by comparing output of the model with the official Nigerian national accounts. Since the initial conditions were estimated from the input-output study by Carter (1960), the output of the model was not strictly comparable with the official accounts. Thus, tuning of the model was based on casual comparison of growth rates and trends rather than formal statistical procedures. Because of the economic disruption after 1966, due to civil war, the period 1959-66 was used as a basis for tuning.

2/ Since there are several matrixes of parameters, particularly the input-output table, disaggregation will tend to increase the data requirements exponentially rather than linearly.

As we noted above, the greatest source of uncertainty was in the investment parameters and the change of all parameters over time. For example, large-scale manufacturing has been growing at the rate of 10 to 15 percent per annum over the period. This growth rate can only be explained in terms of import substitution processes. Although we used the work of Clark (1969) to approximate the changes in the import coefficients associated with this sector, considerable uncertainty still remained, and the coefficients were further adjusted to make the model behavior coincide with historical results in the tuning-up process.

There are two serious shortcomings to the validation of the model. First, the period of seven years used for validation was not sufficiently long to enable confident use of the model in long-term planning. Second, many of the variables (such as investment) used in comparing the simulated results with the real-world are subject to a good deal of error in real-world estimation. This can be corrected only by better collection of national statistics.

The following series of runs illustrates the capability of the model. In Table 7.3, Run 1 is a base run for the period 1959-66, with exports held constant at a level approximating the actual export levels for those years. In Run 2, the level of agricultural exports has been exogenously increased by £10 million for the period. The multiplier effect on the total economy is seen to be approximately 3. (See Table 7.3.) When the original increase in exports is allowed in agricultural contributions to GDP, the multiplier effect is highest in the nonagricultural economy. Figure 7.3 traces these results over time for both the agricultural and nonagricultural economies. In this case, it takes from three to four years for the full multiplier effect to be achieved. The value of the model in providing a more accurate index of the effect of agricultural policy on the total economy is obvious from these results. Run 3 of Table 7.3 shows similar results for the case of an

TABLE 7.3
Multiplier Effects on the Economy of an Exogenous Increase in Agriculture and Oil Exports

Run	Agricultural Contribution to GDP	Nonagricultural Contribution to GDP	Total GDP^a/ at Market Prices
	Year 1966/67 - Million Nigerian Pounds		
1. Base run	707	630	1,461
2. Exogenous increase of £10 m. in ag. exports 1959-1966.	727	643	1,497
Increase over base run.	20	13	36
3. Exogenous increase of £10 m. in oil exports, 1959-1966.	708	640	1,473
Increase over base run.	1	10	12

a/ Includes government revenues and indirect taxes.

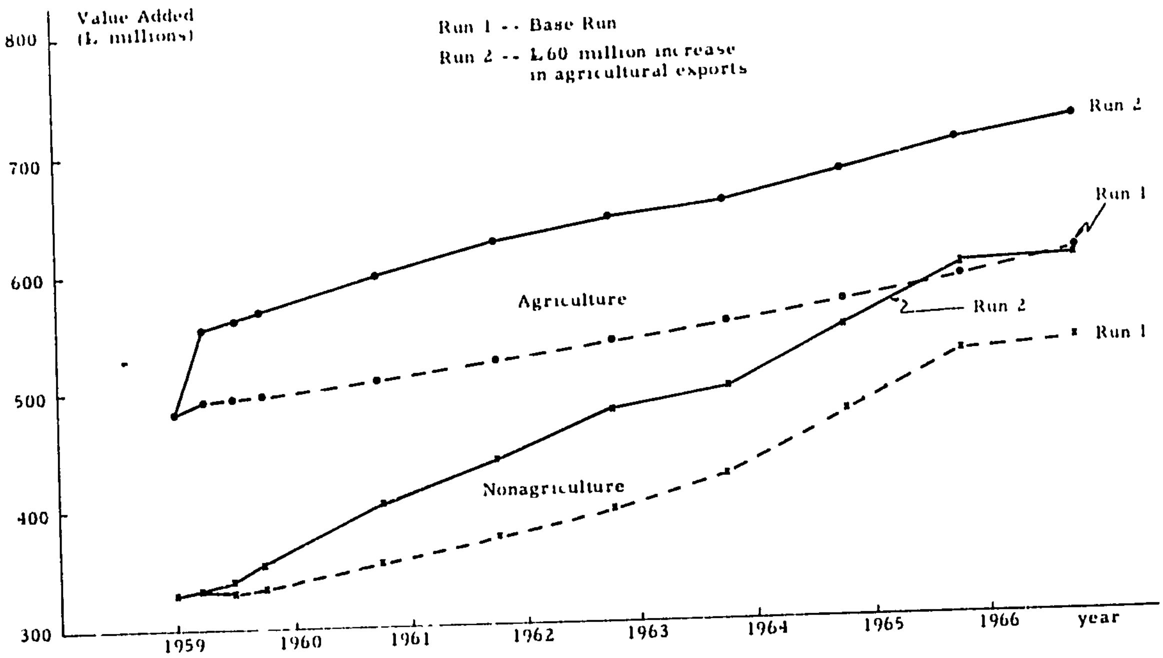

Figure 7.3. Effect on the economy of an exogenous increase of £ -60 m. in agricultural exports.

exogenous increase in oil exports. As expected, because of profits remitted abroad and higher import requirements, the multiplier effects are considerably smaller.

Discussion and Conclusions

The model simulates behavior in the real-world over the period 1959-66 with reasonable accuracy. Ideally, however, a period longer than seven years would be required for confident validation. Because only key variables were used in each component of the model, it is not generally able to simulate minor year-to-year fluctuations in the economy, although longer-term trends will usually be reflected by the model.

The essential usefulness of the model is its capability of interacting with detailed sectoral models to enable modeling of intersectoral multiplier effects and policy evaluation with respect to the total economy. The model also has value in making macro-economic projections, taking into account interactions between sectors. This promises improvement over conventional economic planning projections where such interactions are not formalized or are ignored. Furthermore, the model does enable a more complete understanding of the economic growth process, since it disaggregates the economy by production sectors, e.g., agriculture, manufacturing, oil, transport, etc., and allocates the output of each sector by end use, i.e., consumption, investment, exports and intermediate products. This matrix of interacting sectors and uses pinpoints the growing points of the economy.

There are many directions in which the model could be extended to make it more realistic and useful. First, more variables could be introduced into the determinants of consumption and investment. For example, Holland (1966) in a simulation model of the Venezuelan economy incorporated the notion of expectations in investment behavior by including oil exports as an element of an aggregate investment equation. While a similar argument may hold for investment in Nigeria, we felt that, for the present purposes, this would detract from the generality of the model. However, in any application to planning for a specific country, such adjustments may be necessary to account for the uniqueness of the economy. What we have proposed in the present model is a skeletal framework of a few key variables upon which further refinements can be made in any specific application.

Second, the model needs to be further developed to include prices as endogenous variables of the system. In Holland's model of Venezuela, prices are a function of capacity utilization where capacity is defined in terms of the capital stock. Again, the generality of this approach is questionable since many other factors are likely to be important in determining the supply function of an industry. Indeed, in the case of Nigeria, Kilby (1969) has argued that entrepreneurial ability is a critical determinant of supply response in Nigerian manufacturing. Furthermore, for Nigeria, where price movements both absolute and relative were not substantial during recent history, the model's results are not greatly affected by the assumption of constant prices. However, a great deal of generality could be gained by including an additional component incorporating money supply, exchange rates and price determination. This is necessary for the model to be applied to countries with significant price instability.

Finally, further attention to the agricultural sector should enable the model to be directly used in agricultural planning, independently of a detailed agricultural sector model. For our purposes, we have contracted the agricultural economy into one sector with a total output greater than the remaining nine sectors. Within the existing framework the agricultural sector could be divided into a food sector and export crop sectors to evaluate the impact of various production campaigns. Alternatively, where competition between crops for land and capital are of interest, changes in the model structure would be required.

CHAPTER VII : APPENDIX

A Supplementary Model of the National Economy for Agricultural Sector Analysis

THIS APPENDIX GIVES a mathematical description of the nonagricultural and national accounts model. The overall picture of the model has been given by Figure 7.1 in the body of the chapter. There is a switch in the program which is set to enable the model to run as a separate entity or in conjunction with the detailed agricultural sector model. In the following description it is assumed that the detailed agricultural sector model is available to provide estimates of agricultural investment and exports, food consumption and agricultural disposable income on a regional basis. The alternative method of computing these estimates for independent runs is shown in footnotes.

Exports

All exports are computed exogenously to the model. Exports of agricultural commodities are provided by the agricultural sector model and summed by Equation (E1).1/ Exports of residual crops, mainly timber, are assumed to grow at a fixed rate. Associated with agricultural exports are exports of transport and distribution services, which are obtained in Equation (E2) by allocating a proportion of the marketing margins computed by the agricultural models to these sectors.

(E1) $$EXTD_1(t) = \sum_{i=1}^{2} VALXPP_i(t)$$

where:

$EXTD_1$ = total agricultural exports--thousand £/year

$VALXPP_i$ = value of agricultural exports at producer or processor prices in the i^{th} region--thousand £/year (computed in the agricultural model).

(E2) $$EXTD_6(t) = 0.3* \sum_{i=1}^{2} TVAMEX_i(t)$$

$$EXTD_{10}(t) = 0.7* \sum_{i=1}^{2} TVAMEX_i(t)$$

where:

$EXTD_6$ = transport exports--thousand £/year

$EXTD_{10}$ = service and trade exports--thousand £/year

1/ *For independent runs, agricultural exports are assumed to grow at a rate reflecting past historical trends.*

$TVAMEX_i$ = marketing margin or export crops in the i^{th} region--thousand £/year (computed in the agricultural model).

Oil exports are included simply as an exogenous time series, $EXTD_5(t)$. This time series may reflect pessimism or optimism concerning the outlook for oil exploration.

Consumption

The consumption component first computes the per capita disposable income of each class of consumers. The disposable income of the agricultural population is the sum of the disposable incomes provided by the agricultural model (Equation (C1)). Profits retained, purchased inputs and cash food consumption have been subtracted from cash income to yield income available for nonagricultural consumption.2/

$$\text{(C1)}\quad PDSINC_1(t) = \left(\sum_{i=1}^{2} TAGDIP_i(t) + PINC_2(t)\right)/POP_1(t)$$

where:

$PDSINC_1$ = total per capita disposable income in agriculture--£/year

$TAGDIP_i$ = total agricultural disposable income in the i^{th} region--thousand £/year (computed in the agricultural model)

POP_1 = total agricultural population--thousands/year (computed in the population model)

$PINC_2$ = personal income generated by the residual agricultural sector--thousand £/year (computed in the production component in Equation (P8)).

The disposable income of the nonagricultural population is computed in Equation (C2) as the total of personal income from each nonagricultural sector less expenditure on food. Personal income is computed in the production component as wages and salaries for those employed in modern sectors and average earnings for those self-employed in traditional sectors.

$$\text{(C2)}\quad PDSINC_2(t) = \left(PINCNA - \sum_{i=1}^{2} TFCNAG_i(t)\right)/POP_2(t)$$

where:

$PDSINC_2$ = total per capita disposable income of the nonagricultural population--£/year

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2/ For independent runs of the model, an alternative computation of agricultural disposable income is given by Equation (C1.1)

$$\text{(C1.1)}\quad PDSINC_1(t) = \left(PINC_1(t) + PINC_2(t)\right)/POP_1(t)$$

where:

$PINC_1$ = personal income generated by the main agricultural sector--thousand £/year (computed in the production component in Equation (P8)).

PINCNA = total personal income earned by the nonagricultual population--thousand £/year (computed in the production component by Equation (P9))

$TFCNAG_i$ = total food consumed by the nonagricultural population in the i^{th} region--thousand £/year (computed in the agricultural model)

POP_2 = total nonagricultural population--thousands.

Consumption demand for nonagricultural goods and services is determined by the elasticity of demand with respect to per capita income (Equation (C3)); that is, the relative prices of nonagricultural goods are assumed constant.

(C3) $PCON_{i,j}(t) = ACON_{i,j} * PDSIND_i(t)^{ELAST_{i,j}} \qquad j = 2,...10$

<u>where</u>:

$PCON_{i,j}$ = the per capita consumption of the j^{th} commodity by the i^{th} class of consumers--£/year

$ACON_{i,j}$ = an empirically determined constant

$PDSIND_i$ = the exponentially lagged value of per capita disposable income, $PDSINC_i$--£/year

$ELAST_{i,j}$ = the income elasticity of demand of the i^{th} class of consumers for the j^{th} commodity.

Consumption of food staples is computed by Equation (C4), using estimates of food consumption computed in the marketing mechanism of the agricultural model.[3]

(C4)
$$PCON_{1,1}(t) = \sum_{i=1}^{2} TFCAG_i(t)/POP_1(t)$$
$$PCON_{2,1}(t) = \sum_{i=1}^{2} TFCNAG_i(t)/POP_2(t)$$

<u>where</u>:

$PCON_{i,1}$ = per capita consumption of food by the i^{th} class of consumers valued at producer prices--£/year

$TFCAG_i$ = total food consumed by the agricultural population in the i^{th} region--thousand £/year (computed in the agricultural model)

$TFCNAG_i$ = total food consumed by the nonagricultural population in the i^{th} region--thousand £/year (computed in the agricultural model)

3/ *Alternatively, food consumption is computed in Equation (C3.1) by extending Equation (C3) to cover the main agricultural sector.*

(C3.1) $PCON_{i,j}(t) = ACON_{i,j} * PDSIND_i(t)^{ELAST_{i,j}} \qquad j = 1,...10$

POP_i = population of the i^{th} class of consumers--thousands.

Total consumption of each commodity is then simply the sum of the consumption of each class of consumers (Equation (C5)).

$$\text{(C5)} \quad TCONS_j(t) = \sum_{i=1}^{2} POP_i(t)*PCON_{i,j}(t)$$

where:

$TCONS_j(t)$ = total national consumption of the j^{th} commodity--thousand £/year.

Equations (C6) and (C7) divide this consumption into domestically produced goods and imported goods. Imports are assumed to be a proportion of total consumption, although it is possible for this proportion to vary exogenously to represent import substitution.

$$\text{(C6)} \quad CIMP_j(t) = CIMPP_j(t)*TCONS_j(t)$$

where:

$CIMP_j$ = imports of the j^{th} commodity--thousand £/year

$CIMPP_j$ = proportion of the total consumption of the j^{th} commodity imported.

$$\text{(C7)} \quad DCD_j(t) = TCONS_j(t) - CIMP_j(t)$$

where:

DCD_j = demand for domestically produced consumption goods--thousand £/year.

Domestic consumption demand, DCD_j, becomes part of final demand for domestic production, while total consumption, $TCONS_j$, and imports, $CIMP_j$, are used in the construction of the national accounts.

Investment

Exogenous investment consists largely of public capital formation in the utilities, transportation and services sectors. In each time period, both the total amount of public investment and the allocation between sectors are exogenous variables. Investment in petroleum exploration and production is also included as an exogenous time series projection, since investment in this sector is largely determined by factors outside of the economy. Although investment in the agricultural sector is exogenous to the model, it is computed endogenously in the agricultural model and summed by Equation (I1) to give total investment.4/

4/ *For independent runs of the model, agricultural investment,* $EXOG_1(t)$, *is assumed to grow at an exogenous rate reflecting recent historical trends.*

(I1) $EXOG_1(t) = \sum_{i=1}^{2} CAPDP_i(t) + CAPDPP(t)$

<u>where</u>:

$EXOG_1$ = total investment in the agricultural sector (excluding land development)--thousand £/year

$CAPDP_i$ = investment in agricultural production in the i^{th} region--thousand £/year (computed in the agricultural model)

CAPDPP = investment in agricultural processing--thousand £/year (computed in the agricultural model).

Endogenous investment is computed by Equation (I2). Because of the lack of data, no effort was made to compute replacement investment and inventories separately. Rather, the assumption was made that these investments form a fixed proportion of total investment and are included in the capital-output ratios.

(I2) $ENDOG_j(t) = PENDOG_j*CYMR_j*ROUTD_j(t)$

<u>where</u>:

$ENDOG_j$ = total endogenously derived investment in the j^{th} sector--thousand £/year

$PENDOG_j$ = proportion of output privately produced in the j^{th} sector

$CYMR_j$ = marginal capital-output ratio in the j^{th} sector

$ROUTD_j$ = smoothed rate of change of output of j^{th} sector--thousand £/year (from Equation (P1) of the production component).

Total demands for investment goods by all sectors, excluding households, are given in Equation (I3) as the sum of exogenous and endogenous investment.

(I3) $RINV_j(t) = TEXOGI_j(t) + ENDOG_j(t)$

<u>where</u>:

$RINV_j$ = total demand for investment goods by the j^{th} sector--thousand £/year

$TEXOGI_j$ = total exogenous investment in the j^{th} sector (private and government)--thousand £/year.

These investment requirements of each sector for capital goods are translated into demands for capital goods from each sector by Equation (I4). A matrix, B, of exogenously specified coefficients measures the demand for investment goods from the j^{th} sector generated by one unit of investment expenditure in the k^{th} sector. An analagous set of coefficients determines the demands for imports of investment goods.

(I4) $DIND_j(t) = \sum_{k=1}^{10} B_{j,k}*RINV_k(t)$

$RIIMP_j(t) = BIMP_j * RINV_j(t)$

<u>where</u>:

$DIND_j$ = the demand for domestically produced investment goods from the j^{th} sector--thousand £/year

$B_{j,k}$ = the demand for the j^{th} good generated by one unit of investment in the k^{th} sector

$RIIMP_j$ = the demand by the j^{th} sector for imports of investment goods--thousand £/year

$BIMP_j$ = the demand for imports of investment goods generated by one unit of investment in the k^{th} sector.

<u>and</u>:

$$\sum_{j=1}^{10} B_{j,k} + BIMP_k = 1.$$

Investment by households in residential construction is generated in Equation (I5). This investment is part of domestic investment demand for construction (Sector 6) and is added in Equation (I6) to that generated by Equation (I4). Domestic investment demand then becomes an element of final demand.

(I5) $RESIN(t) = ARESIN * TPOP(t) * PCINCD(t)^{RESELY}$

<u>where</u>:

RESIN = investment in residential construction--thousand £/year

ARESIN = empirically determined constant

TPOP = total population--thousands

PCINCD = exponentially lagged value of average per capita income-- £/year

RESELY = demand elasticity for residential construction.

(I6) $DIND_6(t) = DIND_6(t) + RESIN(t)$

Finally, some investment, such as investment in land clearing, is considered nonintermediate investment in the sense that intermediate inputs are negligible. This investment does not enter final demand but, for national accounting purposes, is included in total investment by Equation (I7).

(I7) $TINV(t) = \sum_{j=1}^{10} RINV_j(t) + RESIN(t) + ONIINV(t)$

<u>where</u>:

TINV = total national gross investment--thousand £/year

$\sum_{j=1}^{10} RINV_j$ = investment of all production sectors--thousand £/year

RESIN = investment of households in construction--thousand £/year

ONIINV = other nonintermediate investment--thousand £/year

Production

Total final demand is the sum of the various demands for domestic production given by Equation (N17).

(N17) $FDY_j(t) = DCD_j(t) + DIND_j(t) + EXTD_j(t)$

where:

FDY_j = total final demand for domestic production of the j^{th} commodity--thousand £/year

DCD_j = domestic consumption demand for the j^{th} commodity--thousand £/year (computed in the consumption component by Equation (C7))

$DIND_j$ = domestic investment demand for the j^{th} commodity--thousand £/year (computed in the investment component by Equation (I4))

$EXTD_j$ = export demand for the j^{th} commodity--thousand £/year (computed in the export component).

Given the vector of final demands, total output, including intermediate demands, is computed by means of the input-output table in Equation (P1).

(P1) $OUT(t) = [I - AIO]^{-1} * FDY(t)$

where:

OUT = a vector (OUT_j, j = 1, 10) of outputs of each sector--thousand £/year

I = the identity matrix

AIO = input-output matrix ($AIO_{j,k}$, j = 1, 10; k = 1, 10) where each element, $AIO_{j,k}$, represents the input of the j^{th} sector required in the production of one unit of the k^{th} good

FDY = column vector (FDY_k, k = 1, 10) of final demands from the k^{th} sector--thousand £/year.

Given the total output of each sector, imports for intermediate use are computed by Equation (P2). It is assumed that these imports are not competitive with local production.

(P2) $RIMP_j(t) = RIMIO_j * OUT_j(t)$

where:

$RIMP_j$ = imports required for the production of the j^{th} commodity--thousand £/year

$RIMIO_j$ = imports required for the production of one unit of the j^{th} commodity.

The inputs of domestically produced intermediate goods are calculated in Equation (P3). Value added is then given in Equation (P4) as the difference between total output and total intermediate inputs, and represents the returns to the factors of production; namely, land, labor and capital. Value added also shows the contribution of each sector to gross national product in the national accounts.

$$\text{(P3)} \quad RINID_j(t) = \sum_{k=1}^{10} AIO_{j,k}{*}OUT_j(t)$$

where:

$RINID_j$ = total of domestically produced inputs in the j^{th} sector--thousand £/year.

$$\text{(P4)} \quad VALAD_j(t) = OUT_j(t) - (RINID_j(t) + RIMP_j(t))$$

where:

$VALAD_j$ = value added in the j^{th} sector--thousand £/year.

Finally, personal income of each sector is the total of wages of the wage earners and income of the self-employed. Earnings of the self-employed are given by Equation (P5) as a proportion of total value added. This proportion is very low for the modern sectors where wage earnings predominate and very high for the traditional sectors.

$$\text{(P5)} \quad SINC_j(t) = (1 - P_j){*}VALAD_j(t)$$

where:

$SINC_j$ = value of earnings of self-employed in the j^{th} sector--thousand £/year

P_j = proportion of value added retained as returns to capital or remitted abroad in the j^{th} sector

$VALAD_j$ = value added in the j^{th} sector--thousand £/year.

Earnings from wage employment are given by Equation (P6). Changes in wage labor productivity are accounted for in Equation (P7).

$$\text{(P6)} \quad WINC_j(t) = RLAB_j(t){*}OUT_j(t){*}WAGE_j(t)$$

where:

$WINC_j$ = value of earning from wage employment in the j^{th} sector--thousand £/year

$RLAB_j$ = the number of labor units of wage employment required to produce one unit of the j^{th} output (see Equation (P7))

OUT_j = total output of the j^{th} sector--thousand £/year (from Equation (P1))

$WAGE_j$ = the average wage rate in the j^{th} sector--thousand £/man-unit.

(P7) $RLAB_j(t) = (1 + RPROD_j)*RLAB_j(t-1)$

where:

$RLAB_j$ = as defined in Equation (P6) above

$RPROD_j$ = rate of increase in labor productivity in the j^{th} sector.

Personal income is then the sum of wage earnings and earnings of the self-employed as in Equation (P8).

(P8) $PINC_j(t) = SINC_j(t) + WINC_j(t)$

where:

$PINC_j$ = personal income arising in the j^{th} sector--thousand £/year.

Personal income of the agricultural population may be computed by Equation (P9) or determined separately in an agricultural sector model. Equation (P10) sums personal income in the nonagricultural sectors, including government. Government value added is exogenously determined.

(P9) $PINCAG(t) = PINC_1(t) + PINC_2(t)$

(P10) $$PINCNA(t) = \sum_{i=3}^{10} PINC_i(t) + GOVALD(t)$$

where:

PINCAG = personal income of the agricultural population--thousand £/year

PINCNA = personal income of the nonagricultural population--thousand £/year

GOVALD(t) = government payments of wages and salaries--thousand £/year.

The National Accounts

The national accounts component computes gross domestic product (GDP) and the trade balance. GDP at factor cost is computed in Equation (N1). Both nonintermediate investment and government value added are exogenous in the model.

(N1) $$GDPF(t) = \sum_{j=1}^{10} VALAD_j(t) + ONIINV(t) + GOVALD(t)$$

where:

GDPF = gross domestic product at factor cost--thousand £/year

$VALAD_j$ = value added in the j^{th} sector--thousand £/year (computed in the production component by Equation (P4))

ONIINV = other nonintermediate investment--thousand £/year

GOVALD = value added by all governments and marketing boards--thousand £/year.

In order to compute GDP at market prices, total exports and imports must first be calculated at F.O.B. prices. Total imports are computed by Equation (N2).

$$\text{(N2)}\quad TIMP(t) = \left(\sum_{j=1}^{10} RIMP_j(t) + \sum_{j=1}^{10} RINIMP_j(t) + \sum_{j=1}^{10} CIMP_j(t)\right)/(1 - DUTIMR)$$

where:

TIMP = total imports at F.O.B. prices--thousand £/year

$RIMP_j$ = imports for intermediate use in the j^{th} sector at market prices--thousand £/year (computed in the production component by Equation (P2))

$RINIMP_j$ = imports for investment use in the j^{th} sector at market prices--thousand £/year (computed in the investment component by Equation (I4))

$CIMP_j$ = imports of the j^{th} commodity for consumption at market prices--thousand £/year (computed in the consumption component in Equation (C6))

DUTIMR = average rate of import duties.

Similarly, total exports are computed by Equation (N3).

$$\text{(N3)}\quad TEXTD(t) = \sum_{j=1}^{10} EXTD_j(t) + VALDMB(t) + DUTEX(t)$$

where:

TEXTD = total exports at F.O.B. prices--thousand £/year

$EXTD_j$ = value of exports of the j^{th} commodity at producer prices--thousand £/year (computed in the export component)

VALDMB = value added by marketing boards--thousand £/year (computed in the agricultural model)

DUTEX = duties on exports--thousand £/year (computed in the agricultural model).

The trade deficit on current account is then the difference between exports and imports, as in Equation (N4).

$$\text{(N4)}\quad DEFCT(t) = TEXTD(t) - TIMP(t)$$

where:

DEFCT = the trade deficit on current account--thousand £/year.

Given the trade balance, GDP at market prices is given by Equation (N5). It will exceed GDP at factor cost by the total of indirect taxes.

(N5) $$GDPM(t) = \sum_{j=1}^{10} TCONS_j(t) + TINV(t) + DEFCT(t)$$

<u>where</u>:

GDPM = gross domestic product at market prices--thousand £/year

$TCONS_j$ = total consumption of the j^{th} commodity--thousand £/year (computed by Equation (C5) of the consumption component)

TINV = total gross investment--thousand £/year (computed by Equation (I7) of the investment component).

Finally, GDP is adjusted by factor payments abroad to give GNP. Most factor payments abroad are made by the oil industry and are included as an exogenous time series.

(N6) $$GNPM(t) = GDPM(t) - NFPA(t)$$

<u>where</u>:

GNPM = gross national product at market prices--thousand £/year

NFPA = net factor payments abroad--thousand £/year.

CHAPTER VIII

National Model Merger of Submodels

IN ORDER TO ADDRESS some of the questions proposed for the Nigerian simulation model to answer, the Northern, Southern and nonagricultural models, or submodels from this chapter's point of view, had to be merged into a national model. This chapter presents a short discussion of each of the three submodels and then discusses the elements of linking the submodels together to form the national model. The major linking component is described, including the interregional trade mechanism and some of the variables which are passed from one submodel to another are discussed. The results from validity and sensitivity tests are presented in this chapter, but the results from policy evaluation experiments on the national model are presented in the next chapter.

Major Submodels of National Model

Northern Submodel

The Northern submodel consists of six interacting components. The cattle production component simulates the outputs of meat and milk from traditional and modern animals, using inputs of TDN (total digestible nutrients) from various sources. The main interaction is with the land allocation component where the quantities of land are determined in the various crops which supply the quantities of TDN in the cattle component.

The agricultural production and marketing component simulates the economic activities of production and marketing for groundnuts, cotton and food. Allocated land comes from the land allocation component, prices for food from the market component and yields from the modernization component. In turn, this component computes average returns to land and labor which are used in the land allocation component. Commodity-specific value added is computed in the production and marketing component and utilized in the national accounts section of the nonagricultural component.

The market component of the overall model simulates the price mechanism of the cash food market which is used in each of the regional models. This component is described in detail below.

The modernization component provides the average yields for the production and marketing component of the Northern submodel.

A sixth component of the Northern submodel is the consumption and budget component. It computes a number of agricultural sector variables needed by the nonagricultural model. These are expenditures for chemical inputs, capital goods and consumer goods. The component also computes values for use in the national accounts section of the nonagricultural model. These include disposable incomes from production and marketing.

Southern Submodel

The Southern submodel is composed of five interacting components. The agricultural production, marketing and processing component computes the production from acreages of traditional cocoa, modern cocoa, traditional palm, modern palm, traditional rubber, modern rubber, food and tobacco by simulating commodity yields and food subsistence levels of the agricultural population. Marketing and processing are modeled, using accounting equations. Input demands are calculated for labor, capital, chemical and biological materials to perform the three functions of production, processing and marketing and provide the main points of interaction with the population and nonagricultural components of the national model.

The land allocation and modernization component of the Southern model simulates farmers' allocation of land to the traditional or modern production of cocoa, palm, rubber, tobacco and food, based upon economic and cultural factors. The calculation of profitability of alternatives provides the interaction with other components of the national model through the utilization of export prices, numbers of farm decision makers from the population component and cash food prices from the market component.

A third component of the Southern model generates world, market, processor and producer prices for the five commodities considered in the previous two components. Two additional components provide further interaction with other components of the national model. The allocation of a modernization budget from the national budget is made by the modernization program and policies component. The accounting component of the Southern model provides outputs for evaluating the performance of the Southern model as a whole as well as providing inputs to the national account section of the nonagricultural model.

Nonagricultural Submodel

The nonagricultural model has a dual purpose within the national model. First, it broadly models the nonagricultural components of the economy to permit the study of key interactions between agriculture and nonagriculture. The nonagricultural model generates the demand for food by the nonagricultural population and the demand for agricultural raw materials for manufacturing. Likewise, the model simulates the supply of agricultural inputs, such as chemical materials and fertilizer, and the supply of consumer goods and services to the agricultural population.

Second, the nonagricultural model summarizes the accounting variables of both the agricultural models and the nonagricultural to construct a national accounts table and a balance of trade table. These include measures of GNP (Domestic) by branch of activity and category of expenditure.

National Model of Interacting Submodels

A diagrammatic conception of the national model is shown in Figure 8.1. The major connections between the three submodels are shown, and the variables that are either exogenous to the system or flow into the system are shown along the left-hand side. Along the right-hand side are variables that either flow out of the system or are used as performance variables in evaluating the system's behavior.

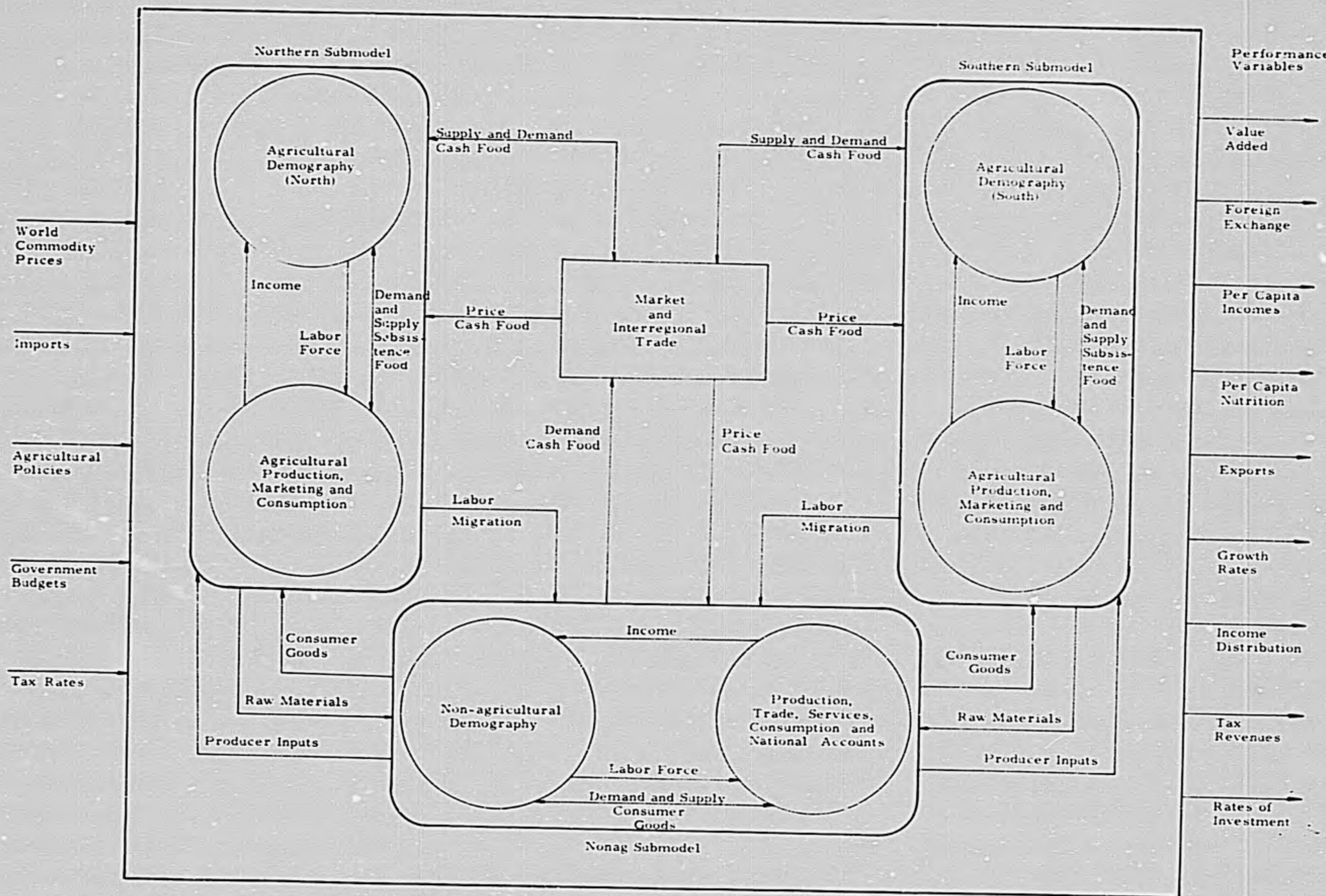


Figure 8.1. National model of interacting submodels.

Each submodel is shown as two interacting parts: (1) demography, production, marketing and consumption, linked together by (2) flow of income, labor force and the demands of supplies of subsistence foods; or, in the case of the nonagricultural submodel, consumer goods. The Northern and Southern submodels are linked directly with the nonagricultural submodel through the flow of consumer goods, raw materials for manufacturing and agricultural producers' input supplied by the nonagricultural submodel. Labor migration can also take place between the agricultural and nonagricultural submodels. A major interaction among the three submodels takes place through interregional trade in food and is simulated by the market and interregional trade component. This component is described in the next section.

Market and Interregional Trade

The main purpose of this component of the national model is to compute the demands for interregional shipments in food between North and South and the resulting regional food prices in the two regions. Food prices in the Northern and Southern models are determined by net supply (regional supply plus shipments from the other region, if any) and demand (regional demand plus interregional trade demand, if any). Regional supply of food is determined by the production components of the Northern and Southern models as discussed in Chapters IV and V. Total demand for cash food in the Northern and Southern models is determined on the basis of price, income and population as described in Chapter VI.

If the local price of food exceeds the price that obtains in the other region plus transportation charges, a proportion of local demand is diverted to an interregional demand for output of the other region. This mechanism is designed so that the model seeks the interregional trade in food that zeros any interregional price differential in excess of transport charges.

Interregional transportation costs are computed endogenously as a function of supply and demand for such transportation. The model is currently designed to compute the investment required in interregional trade to adjust capacity to demand. Other assumptions regarding this investment stream could be modeled as required.

This component also computes a number of variables necessary in the nonagricultural model and in national accounts. A complete mathematical description of this component is included in the appendix to this chapter.

Sensitivity Runs of the Total Model

The preceding chapters have presented and discussed sensitivity analysis of each submodel. However, these analyses were conducted independently of other submodels and did not consider the major interactions among them. It is the purpose of this section to report a series of sensitivity tests on the total model where parameters judged to be of importance to the total economy are analyzed. In this way, we explore the major interactions (described earlier in this chapter) between the Northern agricultural model, the Southern agricultural model and the nonagricultural model.

Sensitivity analysis of the total model has several useful functions in the overall process of model building. First--and most important for a model of this magnitude and complexity--sensitivity analysis is necessary for understanding the behavior of the model and checking its logical consistency. For example, in the initial testing of the merged model, it was found to be particularly sensitive (and at times unstable) to parameters affecting consumption. Further checking revealed that consumption tended to exceed available personal income. Additional model-building to constrain consumption by income corrected this deficiency. Furthermore, sensitivity analysis is a useful device for exploring in detail the complexity of interactive and feedback effects. Only through a complete understanding of these processes can the policy results of the model be adequately conveyed to a policy maker.

Second, sensitivity analysis helps in exploring the various policy implications of the model. By varying parameters dependent on agricultural policy, tentative policy conclusions can be reached. Some of these parameters, such as the yield of food, can be explicitly treated in policy runs of the model where various modernization programs increase yields. Other parameters, such as the proportion of marketing loss for food or the population's birthrate, are not explicitly linked with policy instruments but are fixed exogenously in the model. However, if the model proved to be very sensitive to these parameters, further model-building to include the relevant policy instrument, e.g., food storage program or birth control, would be indicated.

Finally, the sensitivity runs are useful in pinpointing the data requirements of the model. Because much uncertainty is associated with many parameters of the model, it is of interest to know whether this is of consequence in policy formulation. In the present sensitivity analysis, each parameter was varied from the most likely value by approximately one standard deviation to reflect the uncertainty associated with a given parameter.

The runs reported here are summarized in Tables 8.1, 8.2 and 8.3. The parameters tested have been classified into three groups: (1) crop yields in Table 8.1; (2) other parameters of the agricultural model in Table 8.2, and (3) parameters of the nonagricultural and population model in Table 8.3. In the presentation of the model's results, eight key macro-economic variables have been selected. The first two (see Table 8.1), agricultural and nonagricultural value added in current prices, reflect the distribution of income between the agricultural and nonagricultural populations. GDP is presented at current prices and also converted to constant prices to measure real output. The price of food in the North is an indicator of major shifts in demand and supply of food. The shipment of food from north to south reflects changes in interregional trade, a major interaction tested here. The final two columns show changes in agricultural exports and the trade surplus (total exports minus imports). These changes will not always be in the same direction, since the trade surplus includes changes in total imports. In all cases except the trade surplus, results are given as the percentage deviation from the base run in year 1985, i.e., a simulation run of 32 years. Because the trade surplus may be positive or negative, percent changes are not always meaningful and the result shown is the deviation from the base run in millions of Nigerian pounds.

A series of sensitivity analyses on the parameters affecting yields is presented in Table 8.1. Run 1 shows that an increase in the modern yield of groundnuts has large effects on the national variables due to a 35 percent increase in total agricultural exports.[1/] This run is an excellent illustration of the importance of the

1/ This run assumes a modernization program that considerably expands the production of groundnuts over that experienced with current traditional practices.

TABLE 8.1
Results of Sensitivity Tests of Yield Parameters on the Total Model.

Run	Parameter(s) Tested	Definition of Parameter	Value in base run	Value in sensitivity run	Performance Variable							
					Percent Departure from Base Run							mill. $ from base run
					Value added in agriculture	Value added in nonagriculture	Gross domestic product (current prices)	Gross domestic product (constant prices)	Price of food in the North	Shipment of food from the North to South	Total agricultural exports	Trade surplus
1	PYM(1)	Yield of modern groundnuts (lbs./acre)	1000	1250	7.2	8.5	7.8	7.2	2.1	3.7	34.6	327
2	YPER2M(2)	Coefficient determining yield of modern cocoa	1.0	1.2	4.5	6.2	5.4	5.0	1.5	1.9	11.2	400
3	YPER2M(6)	Coefficient determining yield of modern rubber	1.0	1.2	8.6	11.1	9.6	8.9	2.7	2.1	5.5	-65
4	PYT(3)	Yield of traditional food in the cotton-groundnut-food region (lb./acre)	600	750	3.3	3.9	3.6	3.4	.5	2.8	13.2	100
5	PYM(4)	Yield of modern food in the food only region of the North (lb./acre)	9000	10,700	-16.0	-.2	-6.7	6.8	-42.8	30.1	.0	86
6	YF1(1)	Yield of traditional food-the cocoa region (lb./acre)	6550	7500	.4	.5	.4	.3	.4	-.4	.5	-10
7	YF1(4)	Yield of traditional food in the annuals region of the South (lb./acre)	6550	7500	-1.2	-1.2	-1.2	-1.0	-.6	-3.6	0	94
8	YF2(1)	Yield of modern food in the cocoa region (lb./acre)	11,900	14,000	.1	.1	.1	.2	-.2	-1.4	.1	-6

TABLE 8.2
Results of Sensitivity Tests of Some Parameters of the Agricultural Model on the Total Model.

Run	Parameter(s) Tested	Definition of Parameter	Value in base run	Value in sensitivity run	Performance Variable: Percent Departure from Base Run — Value added in agriculture	Value added in nonagriculture	Gross domestic product (current prices)	Gross domestic product (constant prices)	Price of food in the North	Shipment of food from the North to South	Total agricultural exports	mill. Ȼ from base run — Trade surplus
9	E10(4)	Coefficient determining rate of diffusion in food only region of the North	.4	.6	-7.5	-.4	-3.3	1.7	-16.2	13.4	.0	27
10	CIUDB(2)	Coefficient determining rate of diffusion for cocoa on bush land	.01	.03	4.0	5.4	4.9	4.9	.1	8.9	8.0	-126
11	C9(1)	Proportion of groundnuts marketed after allowing for marketing loss	.9	.85	-.7	-.8	-.8	.0	.0	-.6	-3.2	-34
12	C9(4)	Proportion of food from food only region of the North marketed after allowing for marketing loss	.75	.70	2.2	-.2	.8	-1.2	6.6	-3.7	.0	3
13	PLOSS(1)	Proportion of cocoa marketed after allowing for marketing loss	.85	.90	.2	.6	.4	.5	-.2	-1.3	5.5	-6
14	CALPP	Calories consumed per person per year by the agricultural population (thousands)	694	600	-2.1	2.6	1.0	1.7	-2.6	2.3	4.1	-164
15	CW2	Coefficient determining the trend in world prices for groundnuts (% change/year)	-.02	-.01	3.3	3.6	3.4	3.1	1.0	1.3	14.3	'23
16	BPF(1,4)	Price elasticity of supply for food from the food only region of the North	1.5	1.0	.4	-.5	-.1	-1.8	6.6	-1.6	-3.9	-40

TABLE 8.3
Results of Sensitivity Tests of Nonagricultural and Population Parameters on the Total Economy.

Run	Parameter(s) Tested	Definition of Parameter	Value in base run	Value in sensitivity run	Performance Variable							
					Percent Departure from Base Run							mill. ₺ from base run
					Value added in agriculture	Value added in nonagriculture	Gross domestic product (current prices)	Gross domestic product (constant prices)	Price of food in the North	Shipment of food from the North to South	Total agricultural exports	Trade surplus
17	RUM(1,1) RUM(2,1)	Rate of rural urban migration in the North-male and female (% of ag. population/year)	.0075 .005	.02 .012	7.7	-4.5	.1	-6.4	26.5	-14.5	-3.8	178
18	RUM(2,1) RUM(2,2)	Rate of rural-urban migration in the South-male and female (% of ag. population/year)	.02 .01	.035 .02	-2.1	.9	-.3	.0	-1.4	-14.5	1.1	2
19	ELASFP(1)	Food price elasticity of demand of the Northern nonagricultural population	-.30	-.45	-1.0	.2	-.2	.2	-1.4	.9	.9	-5
20	ELASFY(1)	Food income elasticity of demand of the Northern nonagricultural population	.32	.50	.7	-.1	.2	-.1	1.1	.4	-.9	0
21	RSN	Parameter determining the rate of growth of the Southern nonagricultural income relative to the North	.0	.2	-.9	.1	-.3	.2	-1.6	16.0	.4	-7
22	CYMR(3)	Capital-output ratio in small manufacturing	.5	.75	.1	.0	.0	.0	.0	.0	.0	-17
23	ELAST(4,1)	Income elasticity of demand of the ag. population for small trade-services	.6	1.0	1.9	8.9	5.7	5.4	1.4	6.7	.0	-48
24	FLAST(10.2)	Income elasticity of demand of the nonag. population for large manufacturers	1.0	1.3	-1.0	-.1	-.4	-.4	-.1	-.2	.0	-216

interactions between agriculture and nonagriculture discussed in Chapter VII. Since exports account for about 17 percent of the value added in agriculture, the 35 percent increase in exports causes a direct increase of 5.9 percent in agricultural value added. The remaining 1.3 percent increase in value added in agriculture, of the total increase of 7.2 percent, is explained by the increased demand for food. This occurs as a result of increased demand for nonagricultural goods generated by the groundnut producers and a consequent increased demand for food by the nonagricultural population. This process produces a multiplier effect on the increase in groundnut exports. Note that because the income elasticities of demand for nonagricultural goods are higher than for food, the effect on nonagricultural value added is relatively greater. The price of food in this run increases significantly mainly due to demand effects. Since groundnuts and cash food do not strongly compete in the Northern model, the increased profitability of groundnuts relative to food does not appreciably decrease the supply of food. The demand for cash food is increased by the higher incomes of the nonagricultural population, and this increased demand raises prices.

The results of Run 2 and Run 3 showing increases in the modern yields of cocoa and rubber, respectively, are similar to Run 1. The results for rubber (Run 3) are more complex due to the interaction with palm in Region 3 of the South. The limitations of the model in representing the domestic palm market have been discussed in Chapter V and are further borne out by the high sensitivity shown in this run.

In Run 4, the yield of traditional food in the groundnuts-cotton-food subregion of the North has decreased the land and labor required for subsistence purposes and enabled a 13 percent increase in exports, mostly groundnuts. The increase in the price of food here is an interesting example of how supply and demand interact in the food market. The increased food yield has a negligible impact on the supply of food for the reason cited above. However, the resulting increase in exports and nonagricultural incomes increases the demand for food, offsetting the supply response and raising food prices slightly.

In contrast with Run 4, an increase in the yield of modern food in the food-only zone (Middle Belt) in Run 5 has a depressing effect on the economy. There is now no corresponding increase in exports and, hence, food demand. The effect then of the increased yields is to drop food prices and value added in agriculture. Thus, demand for nonagricultural goods by the agricultural population is decreased. However, because food prices decreased, the nonagricultural population spends less on food and more on nonagricultural goods, and the net effect on nonagricultural value added is negligible. In terms of real income, total GDP is increased, although this occurs in the nonagricultural sector at the expense of the agricultural sector. A further significant effect of the increased food yields is the increased shipment of food to the South resulting from the lowered production costs in the North.

Run 6 and Run 8 show the effects of an increase in food yields in the cocoa-food sector of the South. Very similar results to Run 4 (increased food yields in competition with exports in the North) are obtained, although the effects, particularly on exports, are much smaller. As in the case of the North, an increase in yields in the food-only sector of the South has a depressing effect on the economy as shown in Run 7.

Run 1 to Run 5 provide some tentative policy conclusions. In regard to export crops, these runs show that efforts to increase output of export crops are likely to produce strong positive effects on the total economy. However, increased output of food has the effect of redistributing income from agriculture to nonagriculture unless there is a concomitant increase in agricultural exports. Finally, we note that some of the parameters varied in these runs, particularly yields of export crops, produced relatively large changes in the performance variables of the model. Thus, predictive ability of the model is likely to be increased by further data on these parameters.

Table 8.2 shows sensitivity testing of a variety of parameters of the agricultural models. The coefficients determining the rate of diffusion of new technologies are varied in Run 9 and Run 10. These runs give similar results to those for Run 5 and Run 2 where modern yields of food and cocoa, respectively, are increased. In Run 11, the marketing loss of groundnuts is increased, producing small negative effects on exports and output. The marketing loss for food from the food-only zone of the North is increased in Run 12, producing a significant rise in the price of food. This results in a redistribution of income from nonagricultural sectors to agriculture with very little change in the nonagricultural value added. The increased loss of food causes a decline in real output as measured by GDP at constant prices.

When it is assumed that the daily requirement of the agricultural population for calories is reduced (Run 14), the effect is similar to that for increased food yields in competition with export crops; that is, total exports are increased, producing a positive effect on total GDP and nonagricultural value added. However, food prices decline, shifting purchasing power from agriculture to nonagriculture.

More optimistic projections on groundnut prices in Run 15 produce the expected result of an increase in value added in all sectors with a slight rise in the price of food. The remaining run of Table 8.2 (Run 16) shows the result of decreasing the supply elasticity of food in the food-only zone of the North. The consequent rise in the price of food causes total value added to drop, but with a relatively more favorable effect on agriculture.

In Table 8.3, a series of parameters of the nonagricultural sector and the population model are varied. Run 17 and Run 18 show particularly interesting results for increases in the rate of rural-to-urban migration. In Run 17, this rate is increased for the North. Because the model assumes that labor is the factor limiting production in the North, the supply of food is decreased, producing a 26 percent rise in the price of food. The total effect on the economy is a sharp drop in real output, but with agriculture benefiting relative to nonagriculture. When the rate of rural-to-urban migration is increased in the South in Run 18, the effect is smaller and in the opposite direction. Recalling that the Southern agricultural model assumes a labor surplus, increased migration will not affect food supply. However, demand is decreased slightly because, under the current assumptions, the model produces a lower level of nutrition for the nonagricultural population than for subsistence farmers.

Run 19 and Run 20 show the results of changes in the price and income elasticities for cash food. Despite the importance attached to these parameters by most development economists, the present model seems to be relatively insensitive to variations in them. The reasons for this are not difficult to find. On the whole, the model assumes an elastic supply function for cash food, particularly in the North. Thus, changes in demand price elasticities will have little effect on prices and output. Furthermore, because a high rate of population growth is assumed for the nonagricultural sector, there is a very slow rate of increase in per capita income; hence, the income elasticity of demand has little effect.

In Run 21, a parameter is varied to increase the rate of growth of nonagricultural personal income in the South relative to the North. Other than a large increase in the shipment of food from the North to the South, there is little effect on the performance variables of the system.

Variation in the capital-output ratios used in the nonagricultural model also produced negligible effect on the economy (Run 22). However, the model was quite responsive to variations in the income elasticities of demand for nonagricultural goods in Run 23 and Run 24. An increase in the elasticity of demand of the agricultural population for small services in Run 23 produces significant positive effects on the economy. However, a similar increase in the elasticity of demand for large manufacturers in Run 24 has negative effects. This is because there is a substitution of goods with a high import content and produced by capital-intensive techniques for goods domestically produced by labor-intensive techniques. This is shown in Run 24 by the decrease in the trade surplus despite the fact that the decrease in agricultural and nonagricultural value added experienced in this run would normally reduce imports and increase the trade surplus.

These sensitivity runs illustrate the usefulness of this type of analysis in exploring a complex model. The interactions between agriculture and nonagriculture are particularly important in interpreting the sensitivity runs. In general, variations in parameters of the agricultural model had a greater effect on nonagricultural output. This change in nonagricultural output sometimes produced a strong feedback to agriculture, giving unexpected results.

CHAPTER VIII: APPENDIX

National Model Merger of Submodels

Mathematical Description of the Market Component

THIS APPENDIX contains a mathematical description of the market component that links the Northern, Southern and nonagricultural models through trade in food. The primary purpose of this component is to compute interregional trade in staple food and the regional food prices that result from this trade, regional supplies and regional demands.

The following equations determine demands for interregional trade in food in the northern and southern regions of the total model:

(MKT1) $DCFNS(t+DT) = DCFNS(t) + DT*TM_9*DEMCFN(t)*(PRFD_1(t) - PRFD_2(t) - DPSN)/PRFD_1(t)$

(MKT2) $DCFNS(t+DT) = MIN(MAX(DCFNS(t+DT), 0), DEMCFN(t))$

(MKT3) $DCFSN(t+DT) = DCFSN(t) + DT*TM_8*TDCFS(t)*(PRFD_2(t) - PRFD_1(t) - DPNS(t))/PRFD_2(t)$

(MKT4) $DCFSN(t+DT) = MIN(MAX(DCFSN(t+DT), 0), TDCFS(t))$

(MKT5) $SFNS(t) = DCFSN(t) - DCFNS(t)$

where:

DCFNS = northern demand for southern cash food--thousands of calories/year

DCFSN = southern demand for northern cash food--thousands of calories/year

$PRFD_1$, $PRFD_2$ = food prices in North and South, respectively--£/pound

SFNS = shipments of food from North to South--thousands of calories/year

DPSN = transport cost of South-North food shipments--£/pound

DPNS = transport cost of North-South food shipments--£/pound

MIN, MAX = minimization and maximization operators

TM_8, TM_9 = model parameters that determine the speed of interregional trade demand adjustment to interregional price differential

DT = time increment used in simulation--(nominally .25 year).

Equations (MKT2) and (MKT4) limit interregional trade demand so that it is both non-negative and less than total demand in the importing region. Equations (MKT1) and (MKT3) adjust interregional trade demands (DCFNS and DCFSN) whenever the price in the importing region is greater than the price in the supplying region plus transport cost. These equations interact with the equations for $PRFD_1$ and $PRFD_2$ (Equations (MKT12) and (MKT13) below) to compute interregional shipments which will adjust $PRFD_1$ and $PRFD_2$ so that their difference is the transport cost in the appropriate direction.

Since significantly more trade volume originates in the North than in the South due to large North-South shipments of cattle, groundnuts, cotton, etc., (Hay and Smith, 1970), the transport cost of South-North shipments (DPSN) is assumed independent of the volume of transport, and the North-South transport cost (DPNS) a function of total North-South transport demand and supply. The following equations describe these interactions.

(MKT6) $DPNS(t) = DPNSZ*MAX(1, (DTNS(t)/TCAPI(t))^{TM_7})$

(MKT7) DPSN(t) = a constant parameter value

<u>where</u>:

DPNS = transport cost of North-South shipments--£/pound

DPSN = transport cost of South-North shipments--£/pound

DTNS = demand for North-South transport--thousands of pounds/year

TCAPI = total North-South transportation capacity--thousands of pounds/year

DPNSZ = "normal" North-South transport cost in the absence of excess demand for transport--£/pound

TM_7 = a model parameter that determines the impact of excess transport demand upon North-South transport cost.

Equation (MKT6) augments North-South transport cost whenever North-South interregional transport demand (DTNS) is in excess of supply (TCAPI).

Transport demand, DTNS, is an endogenous model variable determined by Equation (MKT8):

(MKT8) $DTNS(t) = TM_2*TM_3*(300 + 33*T1963) + TM_4*OUTP_1(t) + TM_5*OUTP_2(t) + TM_6*DCFSN(t)$

<u>where</u>:

DTNS = total demand for North-South transport--thousands of pounds/year

$OUTP_1$ = North-South shipments of groundnuts--thousands of pounds/year

$OUTP_2$ = North-South shipments of cotton--thousands of pounds/year

DCFSN = North-South food shipments--thousands of pounds/year

TM_3 = average live weight of cattle shipped North to South--pounds/animal

TM_2 = proportion of animals shipped by road or rail

TM_4, TM_5, TM_6 = weighting coefficients (nominally unity)

T1963 = (YEAR minus 1963)--time referenced to the year 1963.

The first term of Equation (MKT8) computes the weight of cattle shipped south annually. The remaining terms compute the weight of interregional shipments of groundnuts, cotton and food, respectively.

The model computes interregional transport capacity, TCAPI, as a function of investment, TINVT, and a gestation lag, TM_1:

(MKT9) $TCAPI(t+DT) = TCAPI(t) + DT*TINVTD(t)/PTC$

(MKT10) $TINVTD(t+DT) = TINVTD(t) + (DT/TM_1)(TINVT(t) - TINVTD(t))$

where:

TINVTD = lagged transport investment (to account for the capital gestation delay)--thousands of £'s/year

PTC = capital/output ratio--£/pounds/year

TM_1 = gestation delay in capital development--years.

Investment in interregional transport, TINVT, can be an exogenous variable to the model or, alternatively, the model can compute the investment required to approximately keep capacity in balance with demand, DTNS. In the latter case, TINVT is determined as follows:

(MKT11) $TINVT(t) = MAX(TM_{10}*PTC*(DTNS(t) - TCAPI(t)) + PTC*RDTNS(t), 0)$

where:

TINVT = investment in interregional transport--thousands of £'s/year

TM_{10} = a parameter that determines the rate of adjustment of an imbalance in TCAPI

MAX = maximum function to preclude disinvestment

RDTNS = rate of change of demand for transport--thousand pounds/year.

The term, PTC*RDTNS, provides investment to expand capacity as demand increases. The term $TM_{10}*PTC*(DTNS(t) - TCAPI(t))$ provides for adjustment if an imbalance should exist between DTNS and TCAPI while the MAX function eliminates the possibility of negative investment.

Food prices for the northern and southern regions are computed in this component by Equations (MKT12) and (MKT13):

(MKT12) $PRFD_2(t+DT) = PRFD_2(t) + DT*TM_{12}*PRFD_2(t)*(TDCFS(t) + DCFNS(t) - DCFSN(t) - SUPCFS(t))/TDCFS(t)$

(MKT13) $PRFD_1(t+DT) = PRFD_1(t) + DT*TM_{12}*PRFD_1(t)*(DEMCFN(t) + DCFSN(t)$

$- DCFNS(t) - SUPCFN(t))/DEMCFN(t)$

<u>where</u>:

$PRFD_2$ = food price in the southern region--£/pound

$PRFD_1$ = food price in the northern region--£/pound

TDCFS = total demand for cash food in the South (from the population component)--thousands of calories/year

DCFNS = northern demand for southern cash food--thousands of calories/year

DCFSN = southern demand for northern cash food--thousands of calories/year

SUPCFS = southern supply of cash food (from the Southern production model)--thousands of calories/year

DEMCFN = northern demand for cash food (from the population component)--thousands of calories/year

SUPCFN = northern supply of cash food (from the Northern production model)--thousands of calories/year

TM_{12} = a parameter which controls the response of price to net excess demand.

These equations compute prices as a function of past prices and the <u>net</u> excess demand in each region as a proportion of total regional demand.

In the northern region, "food" is disaggregated into grains (dominantly grown in competition with groundnuts and cotton in the northern part of the northern region) and roots grown in the southern part of the northern region (the "Middle Belt"). The market component computes separate prices for these two types of food as follows:

(MKT14) $PM_3(t) = PRFD_1(t)/(CP1(t)*CP2(t) + CP3(t))$

(MKT15) $PM_4(t) = CP1*PM(3)$[1/]

<u>where</u>:

PM_3 = market price of grains--£/pound

PM_4 = market price of roots--£/pound

CP2 = proportion of roots in total cash food--$OUTP_4(t)/(OUTP_3(t) + OUTP_4(t))$

1/ Combining these equations we see that the price index $PRFD_1$ correctly gives the total value of food ($PM_3*OUTP_3 + PM_4*OUTP_4$) when applied to total supply $OUTP_3 + OUTP_4$.

CP3 = proportion of grains in total cash food--(1 - CP2(t))

CP1 = ratio of root prices to grain prices (estimated from regression analysis and assumed constant).

These prices are inputs to the production and marketing components (calls of subroutine AMP) dealing with food grains and root food. (See Chapter IV.)

The market component also computes certain variables required by the nonagricultural model and national accounts. These include the total value of cash and subsistence food (food consumed on farm). For the Northern region model these are computed as:

(MKT16) $TFCNAG_1(t) = (PRFD_1(t)/CPLBN)*PPRS_3(t)*SUPCFN(t)$

(MKT17) $TFCNAP_1(t) = TFCNAG_1(t)*(PP_3(t)*CP3(t) + PP_4(t)*CP2)/PRFD_1(t)$

(MKT18) $TFCAG_1(t) = PP_3(t)*YLD_3(t) + PP_4(t)*YLD_4(t) - TFCNAP_1(t)$

<u>where</u>:

$TFCNAG_1$ = total value of staple food sold in the North (at market prices)--thousand £'s/year

$TFCNAP_1$ = total value of staple food sold in the North (at producer prices)--thousand £'s/year

$TFCAG_1$ = total value of northern subsistence food--thousand £'s/year

$PPRS_3$ = proportion of northern cash food supply actually sold (may be less than 1 if effective demand is less than supply)

SUPCFN = supply of northern cash food--thousand calories/year

PP_3, PP_4 = producer prices of food grains and roots, respectively--£/pound

CP3, CP2 = proportion by weight of cash food that is grain and root, respectively

$PRFD_1$ = aggregate northern food price--£/pound

YLD_3, YLD_4 = total production of food grains and roots, respectively.

In Equation (MKT18) the variable CPLBN is the average number of calories per pound in the aggregate root-grain food bundle:

(MKT19) $CPLBN(t) = CPLBG*CP3(t) + CPLBR*CP2(t)$

<u>where</u>:

CPLBG, CPLBR = calories per pound of food grain and root, respectively.

Equations (MKT20-22) compute the corresponding variables for the Southern regional model:

(MKT20) $TFCNAG_2(t) = PRFD_2(t)*TFPNAG(t)$

(MKT21) $TFCNAP_2(t) = PPRCP_5(t)*TFPNAG(t)$

(MKT22) $TFCAG_2(t) = PPRCP_5(t)*TFPAG(t)$

<u>where</u>:

$TFCNAG_2$ = total value of staple food produced for nonagricultural consumption in the South (at market prices)--thousand £'s/year

$TFCNAP_2$ = total value of staple food produced for nonagricultural consumption in the South (at producer prices)--thousand £'s/year

$TFCAG_2$ = total value of food produced for agricultural consumption in the South--thousand £'s/year

$PRFD_5$ = market price of food in the southern region--£/pound

$PPRCP_5$ = producer price of food in the southern region--£/pound

TFPNAG = total food produced for nonagricultural consumption in the southern region--thousand pounds/year

TFPAG = total food produced for agricultural consumption in the southern region--thousand pounds/year.

Another function performed by the market component is the computation of approximate, interregional trade interactions in the event that either the Northern or Southern region model is run separately. The component, in effect, computes a dummy demand for interregional shipments in food based on projected food prices for the region not being included in the simulation run. Specifically, the following equations apply <u>when the Northern region model is run alone</u>.

(MKT23) $PRFD_2(t) = PRFS63 + TM_{17}*T1963$

(MKT24) $DCFSN = MAX(0, TM_{19}*exp(TM_{15}*T1963)*((PRFD_2(t) - TM_{20}*PRFD_1(t))/PRFD_2(t))^{TM_{22}}$

<u>where</u>:

$PRFD_1$, $PRFD_2$ = market prices of food in the northern and southern regions, respectively--£/pound

PRFS63 = southern food price in 1963--£/pound

T1963 = YEAR minus 1963 (time referenced to year 1963)

DCFSN = southern demand for northern cash food--thousands of pounds/year

TM_{17} = parameter that determines the trend of southern food price

TM_{19} = southern purchases of northern food in 1963--thousands of pounds/year

TM_{15} = parameter that determines rate of growth of southern demand for northern food

TM_{20} = a parameter to account for transportation charges

TM_{22} = a parameter that determines the magnitude of price effects on demand for food from the northern region.

Equation (MKT23) projects southern food prices as an adjustable trend beyond 1963 and Equation (MKT24) computes DCFSN. Similar equations apply when the Southern model is run by itself.

Finally, the market component computes per capita nutritional levels for the rural and urban populations of the northern and southern regions. These variables are defined as follows:

$PCFAG_1$, $PCFAG_2$ = per capita food consumption of rural people in the northern and southern regions, respectively--calories/person-year

$PCFNAG_1$, $PCFNAC_2$ = per capita food consumption of nonfarm people in the northern and southern regions, respectively--calories/person-year.

CHAPTER IX

Using the National Model: Some Illustrative Policy Runs

THIS CHAPTER PRESENTS the results of using the national model to estimate the consequences of following alternative agricultural development policies, programs and projects. Simulations for two sets of alternatives were made. The first set of simulations was based upon the models specified in Chapters IV through VII. After these simulations were run, additional experience and opportunities to interact with Nigerian decision makers and agricultural leaders materialized. Such opportunities are part of the on-going, never-ending task of further developing and improving a simulation model. These opportunities permitted the models reported in Chapters IV through VII to be modified and made more relevant to the problems currently before Nigerian administrators and decision makers. Thus, the second set of simulations is not based on the models presented in Chapters IV through VII; instead, they are based upon modifications of those models. Because such modifications are required in most applications, the second set is particularly helpful in illustrating use of the models presented in Chapters IV through VII.

The simulation analyses presented herein should be interpreted cautiously. Many relationships quantified in the model are preliminary in nature; however, the estimates should indicate in a rough way how the Nigerian economy would perform under the policy situations studied. We should also note specifically that the secessionist attempt forced us to model with inadequate attention to changes in productive resources, economic conditions and behavior resulting from the war. Thus, the consequences of some alternatives (especially those particularly affecting the former Eastern region) may not be as accurately portrayed as they would be by an updated model.

Classes of Policies

Two principal classes of policies were simulated in both sets of runs discussed below: (1) marketing board and export tax policies and (2) production campaigns to modernize crop production. Two additional program alternatives were also analyzed in the second set: a tsetse-fly eradication program for the cattle industry and the investigation of the consequences of alternative levels of production campaign budgets.

The first major policy area investigated was alternative marketing board pricing policies. Most export commodities in Nigeria are handled through so-called "marketing boards" which buy from farmers at one price, perform marketing and other services and sell in world commodity markets at a higher price. Marketing boards, in general, have the power to set producer prices as a matter of policy in order to generate "surpluses" or run at a loss. These producer prices can have significant impacts on producer incentives and, hence, on commodity outputs. With simulation runs incorporating different levels of marketing board surpluses for each commodity, questions can be answered regarding the likely consequences these policies will have on production levels, foreign exchange earnings, agricultural income and other relevant economic performance criteria.

Production campaigns make up the second class of policies investigated here. Promotion efforts aimed at modernizing agricultural production can generate substantial returns to both the public and private sectors. Such modernization may entail the introduction of higher yielding biological varieties and/or the encouragement of improved cultural practices, such as weeding, spacing, time of planting and the application of fertilizers and insecticides. The increase in output can then result in higher incomes for the farmers and increased tax revenues and foreign exchange earnings for the public sector. The nonagricultural population can also benefit from the increased demands from the agricultural sector.

The Consequences of Five Policy Alternatives As Projected By The Models Described in Chapters IV to VII

Five agricultural production and marketing policies in Nigeria are defined in this section, and simulated projections are tentatively evaluated, using the models as described in Chapters IV to VII. Each of these policies or policy combinations has been proposed or actually employed in pilot form in Nigeria at one time or another. A series of simulation runs or projections was made to compare the effects of these five policy alternatives on various economic performance variables over a 28-year period.

The first base run was essentially a status quo agricultural policy situation which involved little, if any, change from recent agricultural policies. No changes were made in the current marketing board policies; that is to say, the marketing boards for groundnuts, cotton, cocoa, palm oil and palm kernel retained approximately 27 to 30 percent of their revenues as an "off-take" over and above their operating expenses. In addition, no crop modernization programs were launched. Thus, this run is a basis for comparison with the possible policy changes considered below.

In the second run, the off-take of the marketing boards above operating expenses was reduced to zero for each of the five export crops. This "nonprofit" marketing board behavior allowed higher producer prices to be paid to the farmers for their export crops during the entire simulated period.

In the third run, a combination of export crop modernization programs was defined and evaluated. This combination involved government programs to modernize groundnut and cotton production in the North, to apply modern methods and productive inputs to traditional palm trees in the palm sector of the South, to replant traditional rubber with modern rubber in the South and to encourage new planting of modern cocoa on bush land in the South. It was assumed that these modernization programs were funded for a 10-year period from 1965 to 1975 to provide the required extension effort, the necessary government-provided biological and chemical inputs and cash subsidies for purchasing inputs and hiring labor to get the programs underway. The following budgets were allocated to these programs during the period of maximum expenditure from 1967 to 1973 (with expenditures gradually increasing to that rate during 1965 and 1966, and phasing down to zero during 1974 and 1975): groundnuts, £3.3 million per year; cotton, £1.7 million per year; new planting of cocoa, £3.0 million per year; replanting of rubber, £3.0 million per year; improvement of traditional palm in palm sector, £1.5 million per year. After 1975, it was assumed that the use of the improved agricultural technology would continue to expand at a sufficiently rapid rate through the natural processes of innovation diffusion among farmers so , at no special public funding would be required.

In the fourth run, both sets of policies tested in the second and third runs were run concurrently--namely, no marketing board off-take combined with the five export crop modernization programs.

In the fifth run, the effect of a food crop modernization program in the Middle Belt was tested. A budget of £5 million per year was assumed to be devoted to the program between 1967 and 1973, the years of peak expenditure. A summary of these five policy alternatives is given in Table 9.1.

Since the model structure and behavioral parameters were roughly validated for the period 1953-65 (and statistical information subsequent to that period was not available), the experimental simulation policies below were assumed to begin in 1965 under conditions otherwise normally evolving from the previous period. (The secession disturbances on structure or economic conditions were necessarily ignored.) The modernization programs involving federal or state funding were assumed to begin in 1965, phase up to the maximum annual spending level within two years, remain at the maximum level for six years, and phase down to zero over the 1974-75 period. The marketing board policies were assumed to continue throughout the entire simulation period.

The general effects of the five policies can be seen in the eight graphs which depict the time paths between 1965 and 1990 for several performance variables in which policy makers might be interested:

Figure	Effect of five policy alternatives on:
9.1	Value of agricultural exports
9.2	Value added in agriculture
9.3	Income available for each agricultural worker to spend on nonfood consumption and investment per year
9.4	Value added in the nonagricultural sector
9.5	Gross domestic product
9.6	Price of food staples in northern Nigeria
9.7	Staple food calories consumed in the nonagricultural sector of northern Nigeria
9.8	Staple food calories consumed in the nonagricultural sector of southern Nigeria

These were selected from approximately 75 performance variables actually incorporated in our model.

As can be seen in Figures 9.1 to 9.5, each alternative strategy has about the same effect on the first five performance variables. The most favorable strategy from the standpoint of agriculture is, as one might expect, a combined strategy of "nonprofit" marketing board operations resulting in higher producer prices for export crops, coupled with export crop modernization programs. Over the 25-year period from 1965 to 1990, this combined strategy resulted in a five-fold increase in the value of agricultural exports, as compared with a little less than two-fold increase expected from following the current status quo policy (Figure 9.1). When the general trend of increasing food production is added in, the combined strategy resulted in a 3.5-fold increase in value added in agriculture as compared

TABLE 9.1
Summary of Policies Tested with the Nigerian Simulation Model.

Run Name	Marketing Board Policy	Crop Modernization Programs
1. Base run (marketing board off-take and no crop modernization)	Off-takes above operating expenses: Groundnut 25% Cotton 25% Cocoa 30% Palm oil 30% Palm kernel 30%	None
2. No marketing board off-take	Off-takes cited above reduced to zero	None
3. Export crop modernization	Same as Run 1	Ten year export crop modernization programs, 1965-1975, with the following maximum annual budgets to provide for extension, biological and chemical inputs, and cash subsidies: Export Crop — Million £ per year Groundnuts 3.3 Cotton 1.7 Cocoa (new planting) 3.0 Rubber (replanting) 3.0 Palm (improve traditional palm in palm sector) 1.5 Changes in inputs, extension personnel, subsidies, and yields are described in the Appendices of Chapters 4 and 5.
4. Export crop modernization with no marketing board off-take	Same as Run 2	Same as Run 3
5. Food crop modernization in Middle Belt	Same as Run 1	Ten-year program, 1965-1975, to modernize food crop production in the Middle Belt at a maximum annual budget of 5 million £ per year to provide for extension, biological and chemical inputs, and cash subsidies. Changes in inputs, extension personnel, subsidies, and yields are described in the Appendix to Chapter 4.

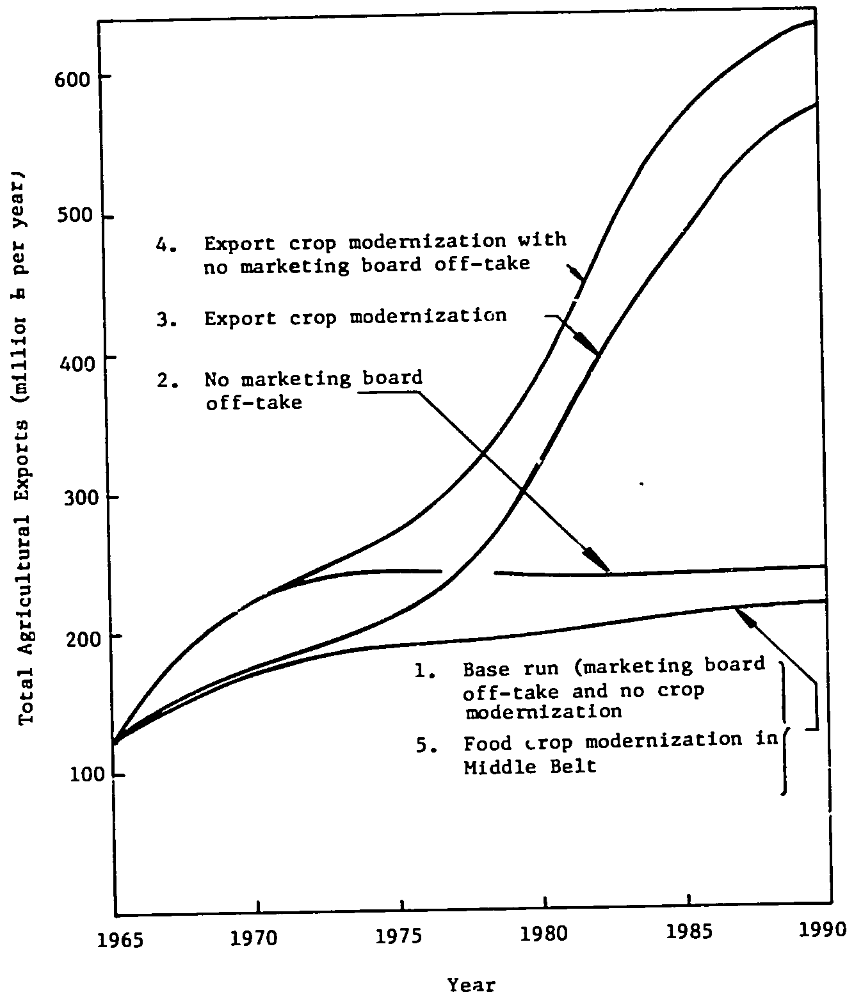


Figure 9.1. Value of agricultural exports from Nigeria 1965-90, under various policies. E ports include groundnuts, cocoa. palm and rubber but exclude cotton and beef.

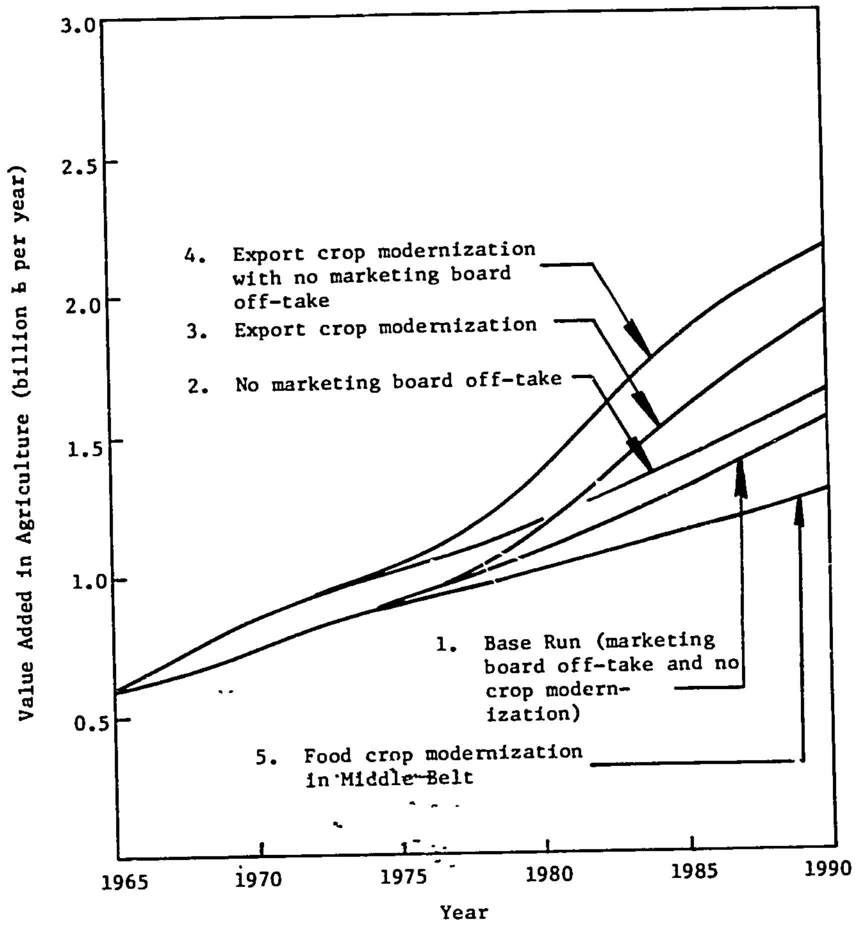
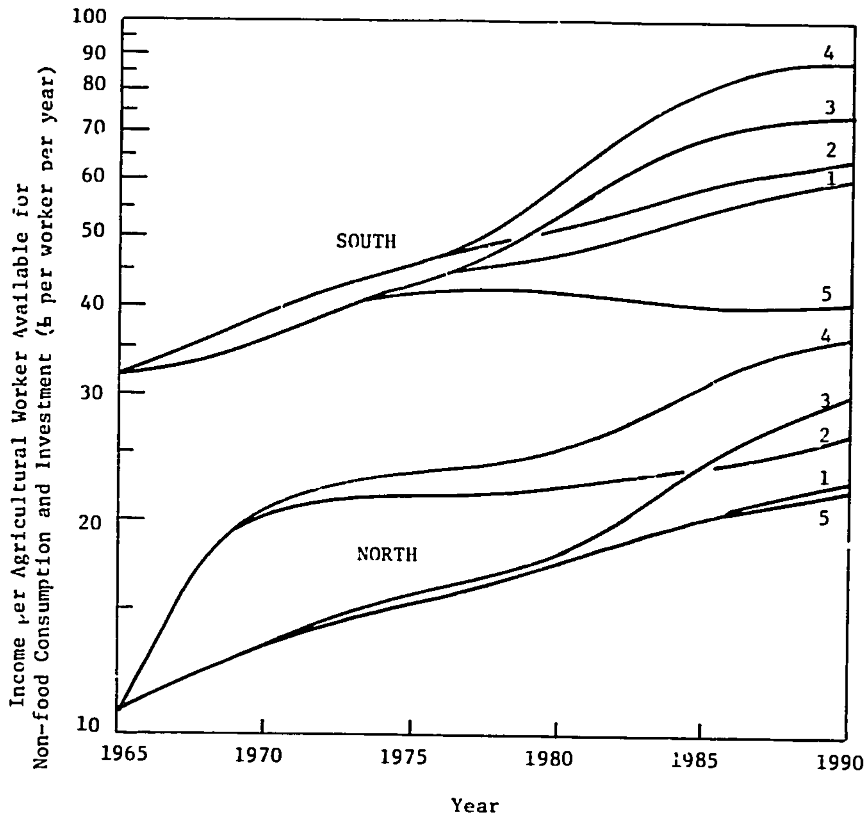


Figure 9.2. Value added in agriculture in Nigeria, 1965-90, under various policies.



Run 1. Base run (marketing board off-take and no crop modernization)
Run 2. No marketing board off take
Run 3. Export crop modernization
Run 4. Export crop modernization with no marketing board off-take
Run 5. Food crop modernization in the Middle Belt
Note: A logarithmic scale is utilized on the vertical axis. In this scaling, parallel lines would indicate that each policy or region is experiencing the same percentage rate of growth or decline.

Figure 9.3. Income for each agricultural worker in northern and southern Nigeria to spend on nonfood consumption and investment per year, 1965-90, under various policies.

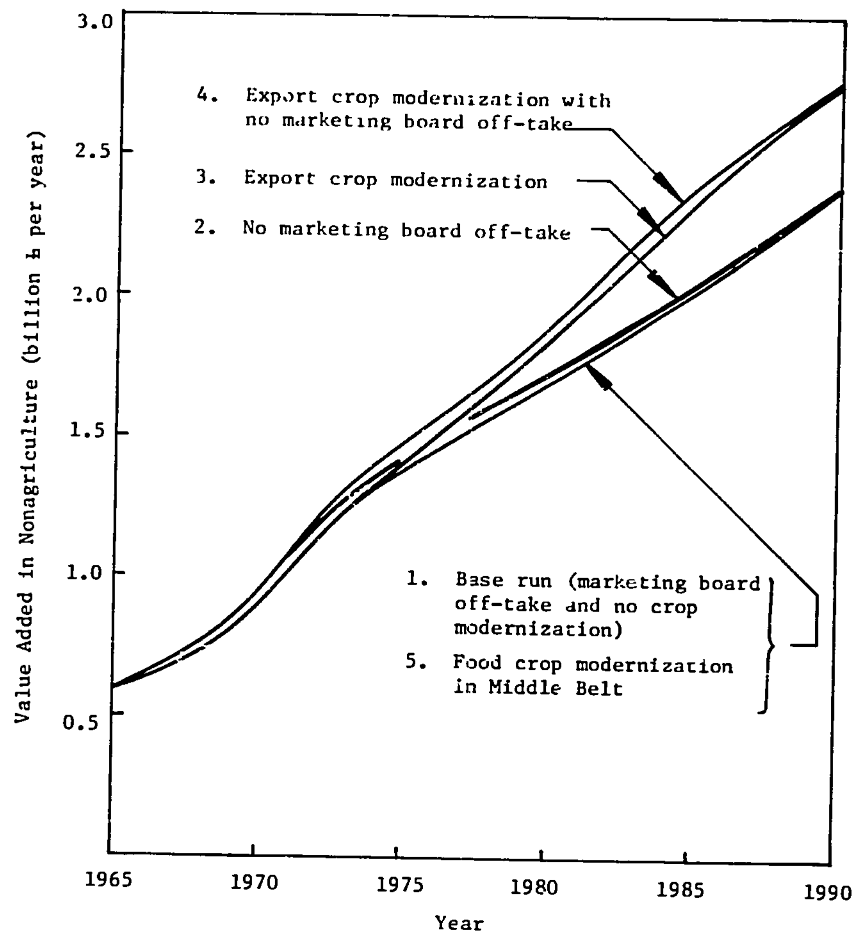


Figure 9.4. Value added in the nonagricultural sector of Nigeria, 1965-90, under various policies.

Note: The funds allocated to the agricultural modernization programs in Runs 3, 4 and 5 were not alternatively invested in the nonagricultural sector in Runs 1 and 2. Also, the effects on federal spending in the nonagricultural sector resulting from the loss of marketing board revenues were not taken into account in Runs 2 and 4.

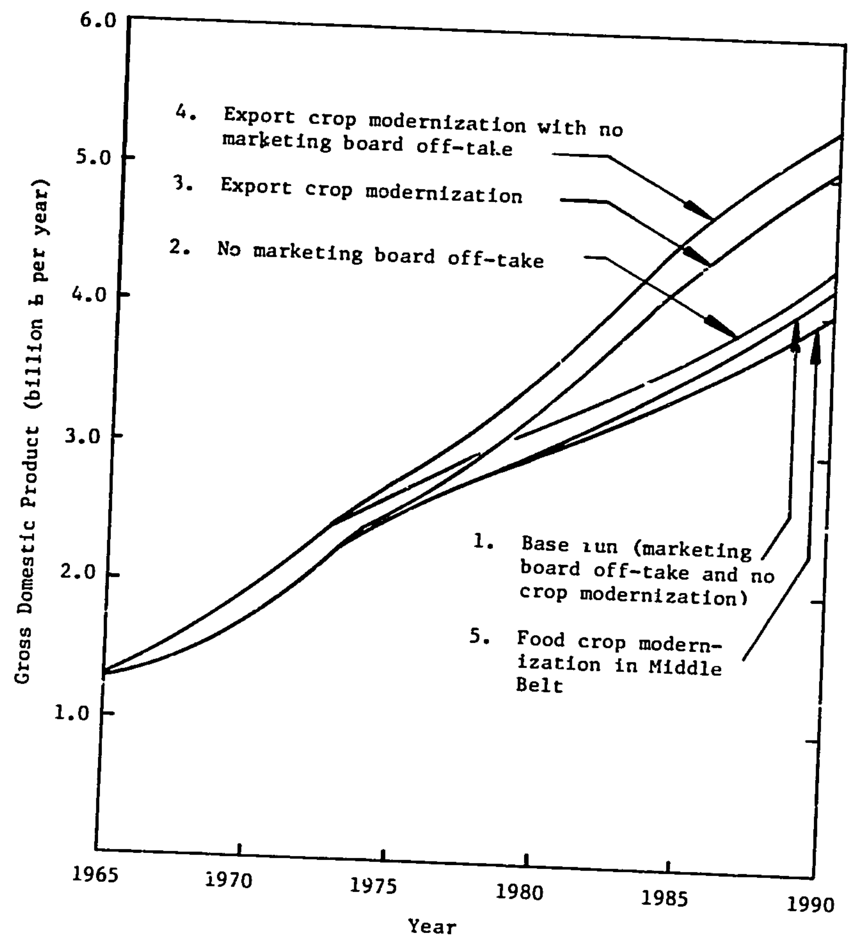


Figure 9.5. Gross domestic product for Nigeria, 1965-90, under various policies.

Note: The funds allocated to the agricultural modernization programs in Runs 3, 4 and 5 were not alternatively invested in the nonagricultural sector in Runs 1 and 2. Also, the effects on federal spending in the nonagricultural sector resulting from the loss of marketing board revenues were not taken into account in Runs 2 and 4.

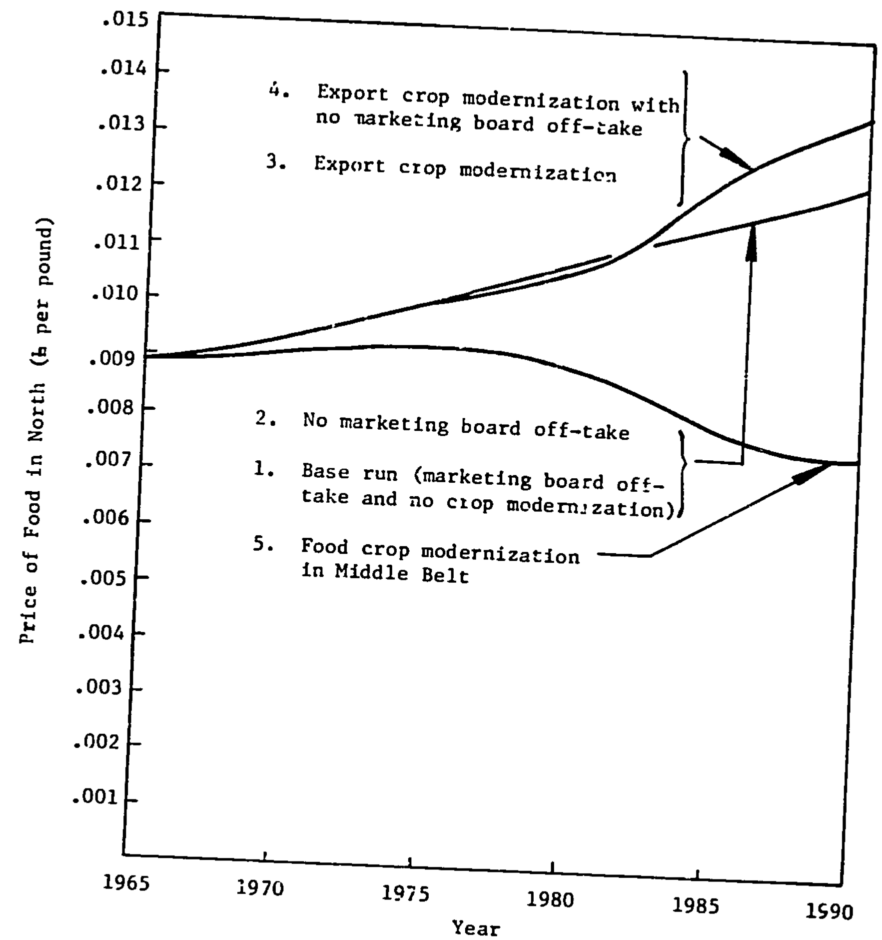


Figure 9.6. Price of food staples in northern Nigeria, 1965-90, under various policies.

Note: The price of food in the South runs approximately ₤ 0.005 per pound higher than the food price in the North due to the transportation costs to ship food from the North to the South.

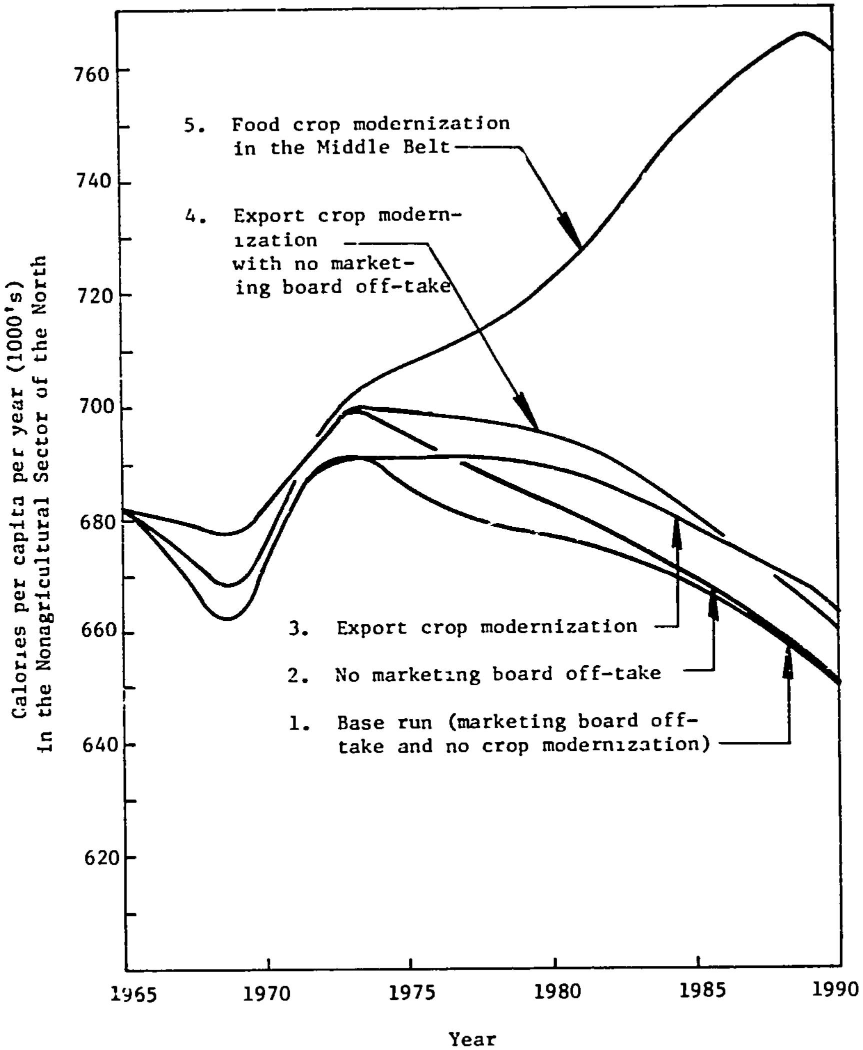


Figure 9.7. Per capita caloric consumption of food staples in the nonagricultural sector of northern Nigeria, 1965-90, under various policies.

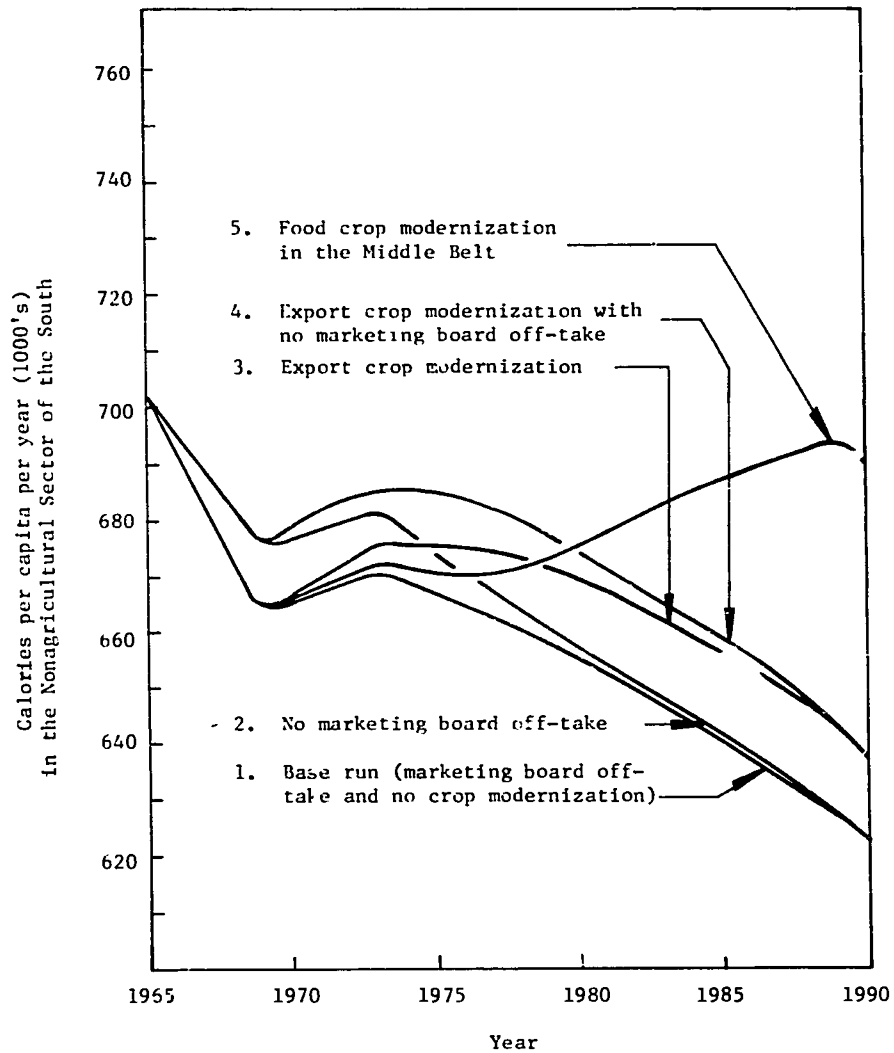


Figure 9.8. Per capita caloric consumption of food staples in the nonagricultural sector of southern Nigeria, 1965-90, under various policies.

with a 2.5-fold increase for the status quo policy (Figure 9.2). The effect of the combined strategy on the income of agricultural workers available for nonfood consumption is shown in Figure 9.3.

Using this index of real per capita income, the combined marketing board-crop modernization policy (Run 4) improves the economic welfare of the agricultural population the most, with a sharper and earlier rate of increase in the North, and a more gradual delayed rate of increase in the higher-income South. The increase in income of agricultural workers available for nonfood consumption feeds back into the economy and causes a long-term increase in the value added in the nonagricultural sector, as shown in Figure 9.4.

The growth in gross domestic product (GDP) (Figure 9.5) resulted from the increased productivity in the agricultural sector and the multiplier effects in the nonagricultural sector. It should be noted, however, that neither the alternative investment in the nonagricultural sector of the funds allocated to export crop modernization programs, nor the effects of reduced federal spending in the nonagricultural sector resulting from the loss of marketing board revenues were taken into account for any of the simulation runs for which these would apply. Comparisons among the strategies in their effects on value added in the nonagricultural sector and GDP (Figures 9.4 and 9.5) should be made with these model deficiencies in mind.

Following a policy of "nonprofit" marketing board operation with no modernization program results in an immediate increase in the first five performance variables, as compared to following the status quo policy. Marketing board policies which would return all marketing board surpluses to the producer would likely result in a substantial boost in export crop production (See Figure 9.1) in the first decade of the program. This is particularly true in the North where the response to favorable prices resulted in an acreage shift into the annual export crops of groundnuts and cotton. In the South, the response was mainly a harvesting response with little shift in acreage of the perennial crops which have long gestation periods. This differential effect between the North and the South is graphically shown in Figure 9.3. Northern farmers enjoyed a very rapid increase in per capita income over the first 10 years while southern farmers enjoyed much less increase in per capita income. The southern farmer, however, had a higher per capita income to begin with. The rate of increase then tapers off after the major adjustments take place as the expected decline in world groundnut prices begins to have an impact on the economy. Increases in export levels and agricultural incomes tapered off approximately eight years after the higher price levels were initiated in the North; the South exhibited a more delayed, gradual rate of growth in these performance variables. Thus, the nonprofit marketing board operation policy alone does not produce any significant long-term effects. After an initial increase in the performance variables, the rate of change quickly returns to the old level, and the time path of the performance variables parallels those for the status quo run at a slightly higher level.

On the other hand, undertaking export crop modernization programs over a 10-year period without a change in marketing board policies (Run 3) had very little short-term effect, as one might expect, but did produce significant long-term effects on the performance variables. Figures 9.1 to 9.5 show that the results from this policy generally overtook and surpassed the results from a changed marketing board policy in about 15 to 20 years. Two factors cause the delay in the effect of modernization programs on the performance variables. First, the program does not immediately reach all farmers as does the change in marketing board prices. Rather, the modernization programs rely on the diffusion of new agricultural technologies among the farm population. During the first ten years, extension workers try to get the new crop technologies adopted by the farmers most likely to adopt new innovations--the better educated and wealthier. Later, the new technologies spread to other farmers by the natural process of innovation diffusion, without much overt effort by extension workers. Second, the perennial crop modernization programs in the South experience an added delay resulting from the five-year average gestation period before new hybrid trees yield any return on investment. Nevertheless, despite the fact that all export crop prices were assumed to be stable or declining during the simulation period, the increased yields and profitability of the modernized cropping alternatives introduced into the model caused a substantial increase in production and incomes relative to current policies. These increases started climbing rapidly approximately 12 years after the onset of the program.

To summarize briefly the discussion of policy runs thus far, we note again that the combination of improving producer export prices and introducing improved export production technology and management stimulated the greatest growth in GDP, agricultural exports and returns to agricultural resources of the five alternatives. The complementarity of these policies instigated greater export crop acreages and yield increases than either one policy did independently. Moreover, all three strategies--the combined strategy and the two policies applied separately--resulted in improvements to both the agricultural and the nonagricultural sectors. However, we should add that the two strategies involving export crop modernization programs did create some long-term adverse effects in the nonagricultural sector. The increased profitability of export crops stimulated agricultural producer demands for nonagricultural goods and, consequently, the nonagricultural population's demand for food. In addition, this profitability caused some producers to switch from food crop production to export crop production. Consequently, the price of food (See Figure 9.6) increased substantially in both programs involving export crop modernization because food demand increased and food supply decreased. Since the income to agricultural resources and GDP are evaluated at current prices, the greater contribution of the programs involving export crop modernization should probably be discounted somewhat to allow for food price inflation, especially from the viewpoint of the nonagricultural population who are entirely dependent upon the cash market for food.

The only policy which did not seem to benefit the agricultural sector as a whole was the strategy of carrying out a food modernization program for the Middle Belt (Run 5); however, it had great benefit for the rest of Nigeria. Modernizing food crops of the Middle Belt of Nigeria to better utilize the agricultural resources in that area, where export crops cannot be effectively grown (and provide the South with the option of specializing more in export crops), had little impact on agricultural exports, value added in agriculture and agricultural incomes. However, the price of food decreased dramatically compared to the other programs (Figure 9.6). The southern agricultural population became less self-sufficient in food, relying more on the food market. Furthermore, when food was modernized in the Middle Belt, shipments of food from North to South increased 270 percent by 1993 compared to the base run. The increased food production contributed heavily to increased caloric intake by the population, especially improving the welfare of the lower income spectrum of the nonagricultural population who are most strongly affected by the cost of food. This occurred initially in the North (Figure 9.7), but after several years when the production was sufficient to allow substantial exports to the South, the food modernization also began to have a positive impact on the per capita caloric intake in the southern cities[1/] (Figure 9.8). Generally, the caloric intake of the nonagricultural population exhibited a gradual down trend for all policies except food modernization, in response to a rapid population growth rate and a substantial population migration from rural to urban areas. Nonagricultural per capita incomes increased, but not enough relative to sharply rising food prices to stimulate increased caloric intakes. While the calories supplied by commercial agriculture declined on a per capita basis, keep in mind that the fishing industry and food produced in private gardens or harvested from wild or domesticated plants or animals, all of which were not considered in the model, would likely respond to high food prices. Consequently, this index of calories available should be considered as only a partial index of the nutritional welfare of the nonagricultural population. Further, the current rate of rural-to-urban migration specified in the model (1.1 percent per year) may be unrealistically high; a lower rate of migration (0.7 percent per year) in other simulation experiments resulted in nonagricultural per capita nutrition levels that were stable or slightly increasing over the simulation period under most policies explored, due to the increased employment in food crop production and decreased unemployment in urban areas. When the model incorporates improved food crop production technology forthcoming from the International Institute of Tropical Agriculture, Nigerian agricultural research stations and other sources, the likelihood of increased caloric intake under most policies should be even further enhanced.

The Consequences of Seventeen Policy Alternatives as Projected by Models Modified on the Basis of Initial Interactions with Nigerian Policy Makers

Some additional policy simulations were done to expand the policy analysis and further illustrate the adaptability of a policy simulation model to new policy questions and changes in the perceived or likely behavior of the economy. After some additional, but limited, interaction with state and national policy makers and planners in Nigeria, the model described in Chapters IV through VII was slightly revised, and the results of a variety of individual policies and combinations thereof were simulated. The submodels reported in Chapters IV through VII underwent varying degrees of revision to correct programming and modeling errors, to incorporate new data and, very importantly, to respecify and further develop the model and its components to handle the questions posed by national policy makers and planners. For the most part, these changes were minor. However, some major modifications and respecifications were made in the Southern regional model described in Chapter V.

To correct one of the major problems in the Southern model. the model of the palm oil market was substantially expanded. First, a domestic market price for palm oil is now computed in addition to the export market price (to which it is indirectly related). The domestic demand for palm oil now responds to changes in the domestic

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1/ *The rise in caloric consumption between 1968 and 1973 noted in Figures 9.7 and 9.8, occurred because the nonagricultural submodel programmed a rise in nonagricultural incomes resulting from a sharp rise in oil revenues starting in 1968 and leveling off after 1973. With the exception of the policy run simulating the effect of food crop modernization in the Middle Belt (Run 5), caloric consumption again started falling off due to rising food prices.*

market price and will only rise as high as the import price plus import tax, at which point excess demand is met with imports, keeping the price from rising higher. These modifications involved changes in Equations (A23) and (P3) through (P6) in Appendix V.B.

The other major modification of the Southern regional model was redefinition of the land allocation profitability criterion (defined in Equation (L5) in Appendix V.B). Rather than the maximum average of discounted net returns over the planning horizon, the profitability index for each land use is now the total discounted sum of net returns. This change was necessary because the other index seemed to cause traditional perennial production to be continued even though a change appeared to be more rational. Since current yields of these crops are steady or falling as the trees age, the maximum average, due to the discounting, would occur in the first year of the planning series, and <u>no</u> account would be taken of projected declining yields from increasingly old and/or diseased trees. To make the land allocation mechanism more realistic, the total sum of net returns is now used rather than the maximum average previously computed. To standardize the comparison of alternative profitability sums from land uses with different planning horizons, the longest planning horizon of the uses being compared (Table 5.1) is the planning horizon for all uses.

Two sets of model parameters used in the original set of five policy runs were changed for runs with the revised model. The rural-urban migration rates in the South of 2 percent per year for males and 1 percent per year for females were reduced to 1 percent and 0.75 percent, respectively, because it was felt that the original migration rates were too high. This had a significant effect on the time path for per capita disposable income available to agricultural workers in the South, as can be seen by comparing Figures 9.3 and 9.23. Also, the value of the constant in the demand equations for cash food staples in the nonagricultural sectors of each region was changed so that the initial caloric consumption at the start of a simulation run was a nominal 694,000 calories per person per year. These initial values had been 716,000 and 801,000 calories per year for the northern and southern regions, respectively, in the policy runs with the original model.

This resulted in lower caloric intake values of the nonagriculture population for runs with the revised model than for runs with the original model (compare the base runs in Figures 9.18, 9.25, and 9.35 with the base runs in Figures 9.7 and 9.8). These adjustments in parameter values need further review.

<u>Description of Policy Runs with Revised Model</u>

Policy experiments were conducted with 17 simulation runs which cover the time period 1953-95 (Table 9.2).

The model is constrained to approximate real conditions from 1953-65, using observed F.O.B. (export) and producer prices for that period. The results analyzed here are for the period 1970-95, with policy implementation beginning in 1971. The year 1970 is thus considered the starting time with simulated "initial" conditions. Projections are carried as far as 1995 in order to give the long run diffusion responses to the production campaigns time to exert their major impact.

With simulation, it is easy to build up the capacity required to test complex combinations of policies, starting with simple runs to evaluate single policies or programs such as reducing marketing board and export taxes before proceeding to such additional complications as alternative production campaigns and infra-structure projects. In addition, a flexible output format allows us to look either at the behavior of aggregated macro-economic variables or to zero-in on, and investigate, the responses on a more micro-level. The policy runs are organized to take advantage of these capabilities.

The 17 simulation runs are grouped into five sets which examine increasingly complex interactions at progressively higher levels of industry and geopolitical aggregation. The runs are summarized in Table 9.2 and described in more detail below. All five sets include Run 1, the base run, as a standard point of reference. The base run projects likely performance under current policies, with no programs to modernize production and with export and marketing board taxes maintained at current levels.

The first set of runs looks at one solution to the problems currently facing the cattle industry in northern Nigeria. The tsetse fly infests the area where cattle would be able to graze in good health, and thus, adversely affects the size and productivity of the Nigerian cattle industry (and the income accruing to northern Nigerians). Run 4 investigates the results of a tsetse-fly eradication program budgeted for £3 million over 10 years, with an eradication cost of £100 per square mile assumed.

Interactions among cash crops (cotton and groundnuts) and food crops in the North are focused-on in the second set of runs, Runs 2, 3, 5, 6 and 7. Runs 2 and 3 compare the effects of cutting off export and marketing board taxes in 1970 or phasing them out over a ten-year period.

In the remaining runs of this set, these taxes are maintained at recent levels (25 percent for cotton and groundnuts), while various combinations of production campaigns are tested. The total budget for production campaigns is assumed to be £40 million spread over a 10-year period. This budget pays for extension salaries, subsidies and overhead expenses. Run 5 simulates programs to increase cotton and groundnut yields to 1,000 and 600 pounds per acre, respectively via extension efforts to introduce new seed varieties and improved cultural practices. In this run, groundnuts get 2/3 of the budget, while cotton gets 1/3. The same end (improved cash crop production) is sought in Run 6 via a food grains modernization program (to hopefully release land for cash crop expansion). If food production is being modernized, the model provides for cotton yields to increase as the labor pressure is eased. This reflects earlier cotton plantings. New technologies in food grain production are assumed to increase yields 2 1/2 times. Here, all £40 million go to food grain programs. All three programs--cotton, groundnut and food grains--are then combined in Run 7, where the budget is split 40 percent, 20 percent and 40 percent to groundnuts, cotton and food, respectively.

Agricultural policies and programs aimed at the southern ecological region are examined in simulation Runs 2, 3, 8, 9 and 10. Runs 2 and 3 again compare the consequences of cutting off export and marketing board taxes or, alternatively, phasing them out. Normal levels of marketing board taxes are assumed to be 20 percent for the three commodities handled by marketing boards (cocoa, palm oil and palm kernels), while export taxes for those three and rubber are 20 percent, 15 percent, 15 percent and 15 percent, respectively.

TABLE 9.2

Policy Simulation Runs on the Revised Model.

Revised Model-- Run No.	Run Definition
1	Base run: Status quo policy--no modernization of production; normal export taxes and marketing board surpluses.
	<u>Policy Run Related to the Cattle Industry</u>
4	Tsetse-fly eradication program, 1971-81.
	<u>Policy Runs Related to Agriculture in the Northern Region</u>
2	Export taxes and marketing board surpluses cut off in 1970.
3	Export taxes and marketing board surpluses phased out from 1970 to 1980.
5	Production campaigns in cotton and groundnuts, 1971-81.
6	Production campaigns in food grains, 1971-81.
7	Production campaigns in cotton, groundnuts and food grains, 1971-81. (Combines Run 5 and Run 6.)
	<u>Policy Runs Related to Agriculture in the Southern Region</u>
2	Export taxes and marketing board surpluses cut off in 1970.
3	Export taxes and marketing board surpluses phased out from 1970 to 1980.
8	Production campaigns in cocoa new planting, cocoa replanting, rubber replanting and palm replanting, 1971-81.
9	Production campaigns in cocoa new planting, cocoa replanting and palm replanting, 1971-81.
10	Production campaigns in cocoa new planting, cocoa replanting, rubber replanting and palm replanting, 1971-81; modernization of palm and rubber processing. (Run 8 plus modernization of palm and rubber processing.)
	<u>Policy Runs Related to Agriculture in Both the Northern and Southern Regions</u>
11	Production campaigns in cotton, groundnuts and food grains in the North, 1971-81; production campaigns in cocoa new planting, cocoa replanting, rubber replanting and palm replanting in the South, 1971-81. (Combines Run 7 and Run 8.)
12	Run 11 plus production campaign in food roots in the Middle Belt, 1971-81.
13	Run 11 with a further improvement in food grain technology after 1980.
14	Run 11 with export taxes and marketing board surpluses cut off in 1970.
15	Run 11 with export taxes and marketing board surpluses phased out from 1971 to 1980.
	<u>Policy Runs Related to Budget Levels for Production Campaigns</u>
11	Production campaigns in cotton, groundnuts, and food grains in the North, 1971-81; production campaigns in cocoa new planting, cocoa replanting, rubber replanting, and palm replanting in the South, 1971-81.
16	Run 11 with half the campaign budget.
17	Run 11 with twice the campaign budget.

Runs 8, 9 and 10 investigate production campaigns in the perennial crops and efforts to improve the processing methods for oil palm and rubber products. The production campaigns assume a budget of £40 million over 10 years to pay for extension salaries, subsidies and overhead expenses. Run 8 involves a modest cocoa new planting program and replanting programs for cocoa, palm and rubber. The budget is split among these programs: 10 percent, 30 percent, 40 percent and 20 percent, respectively. Of the 40 percent in the palm replanting program, 25 percent is used in the areas where palm competes with rubber, and 75 percent is applied to areas where palm has no perennial competitors. Run 9 attempts to highlight the interactive effects of the oil palm-rubber competition (in comparison with Run 8) by not conducting the rubber replanting program and devoting that portion of the budget to palm replanting. The assumed yields at maturity for new planted cocoa and replanted cocoa, palm and rubber are 950, 850, 6,700 and 1000 pounds/acre-year, respectively. The model provides for these yields to gradually increase by 20 percent as farmers gain experience with the new methods of cultivation involved in modern production.

Finally, Run 10 adds to the program of Run 8 investment in modern processing facilities for oil palm and rubber products. For palm, this means Stork hydraulic presses; for rubber it means crumb factories. The investment rate is established at £100 thousand and £200 thousand for palm and rubber, respectively, until a prespecified level of transformation has been reached (50 percent for palm and 100 percent for rubber). While rubber processing is being transformed from sheets to crumb, the model simulates a gradual increase in the domestic industrial demand for crumb rubber up to 50 percent of production.

While the first three sets of runs focus on industry or regional-specific policies, the fourth set of runs, Runs 11, 12, 13, 14 and 15, examines aggregate and interactive effects of agricultural development policies and programs in both the North and the South. Run 11 combines Runs 7 and 8 so that the following production campaigns are carried out simultaneously at the same budget levels (£40 million each in the North and the South) and the same commodity proportions are specified above: modernization of cotton, groundnuts and food grains in the North and new planting of cocoa and replanting of cocoa, palm and rubber in the South.

Run 12 considers the impact of modernizing food production (roots and tubers) in the Middle Belt area of the North, in addition to the modernization programs discussed above. In this way, we can specifically investigate the implications for regional specialization, i.e., the South specializing in perennials and relying on the North for food. However, the modernization of root and tuber food production depends on the development of the requisite technologies, which are not currently available.

In Run 13, a further doubling of food grain yields is assumed to diffuse over a period of four to five years after 1980, as a result of new technologies which may be developed in the next 10 years by national and international research stations. Thus, modern food yields after 1980 are assumed to be potentially five times the current traditional yields experienced in northern Nigeria. This experiment investigates the potential effects on exports (due to cash crop interactions), food prices and consumption.

Runs 14 and 15 combine the production campaigns of Run 11 with the export and marketing board tax policies of Runs 2 and 3, respectively, i.e., the alternatives of cutting off and phasing out these taxes.

The last set, Runs 11, 16 and 17, examines the relative consequences of alternative levels of the campaign budgets. In this way, we can address the question of whether it would be worthwhile to intensify (or de-emphasize) modernization promotion efforts. That is, would likely gains be worth the added expenditures? Or, would the savings from decreased expenditures (saying nothing about the alternative uses for the resources) be worth the projected production losses? Run 1, the standard run, has zero budgets, of course. Run 11 has budgets of £40 million each in the North and South, allocated among the programs, as indicated above. Run 16 halves this budget, while Run 17 doubles it, always with the same proportional allocations to the specific campaigns.

Simulated Policy Results

Policy Run Related to the Cattle Industry

Run 4 simulates a 10 year tsetse-fly eradication program budgeted at £3 million. This analysis does not consider other livestock programs or their potential interactions with other agricultural policies and programs, due to limitations of the current model.[2]

Animal populations,[3] sales and resultant incomes all rise as might be expected (Figures 9.9 and 9.10). Fly-free grazing land (Figure 9.11) experiences a dramatic increase, and the general range condition[4] improves substantially over the base run (Figure 9.12).

In every case, however, the gains attributed to the fly eradication program in Run 4 are temporary in the sense that these performance variables, after an initial increase, return to the same trends as experienced in the base run, although at a higher level. By 1995, all the slopes of the results of Run 4 are either the same as the slopes of Run 1 results, or are approaching these slopes. Thus, the animal population (Figure 9.9) increases rapidly as new grazing areas are opened up. Once these new areas have reached their animal capacity, male and female populations grow at the same rate as in the base run. This causes sales and incomes (Figure 9.10) to also experience the same growth rates as in Run 1 after the initial spurt.

2/ *The study by Kellogg (Kellogg, 1971) considers some additional considerations on mortality loss, marketing costs, etc. which could be incorporated into the model for a more comprehensive analysis of this program and others related to the cattle industry.*

3/ *The initial (1970) cattle population assumed in the model is about five million head (Figure 1.1). Although this figure is somewhat below current estimates of Nigeria's cattle herds, the relative results of Runs* 1 *and* 4 *are still valid.*

4/ *"Range condition" is defined as an index of range-land grass yields and reflects the effects of overgrazing. That is, its value at any time during the simulation period (1970-95) is the ratio of grass yields at that time to grass yields at the initial time (1970).*

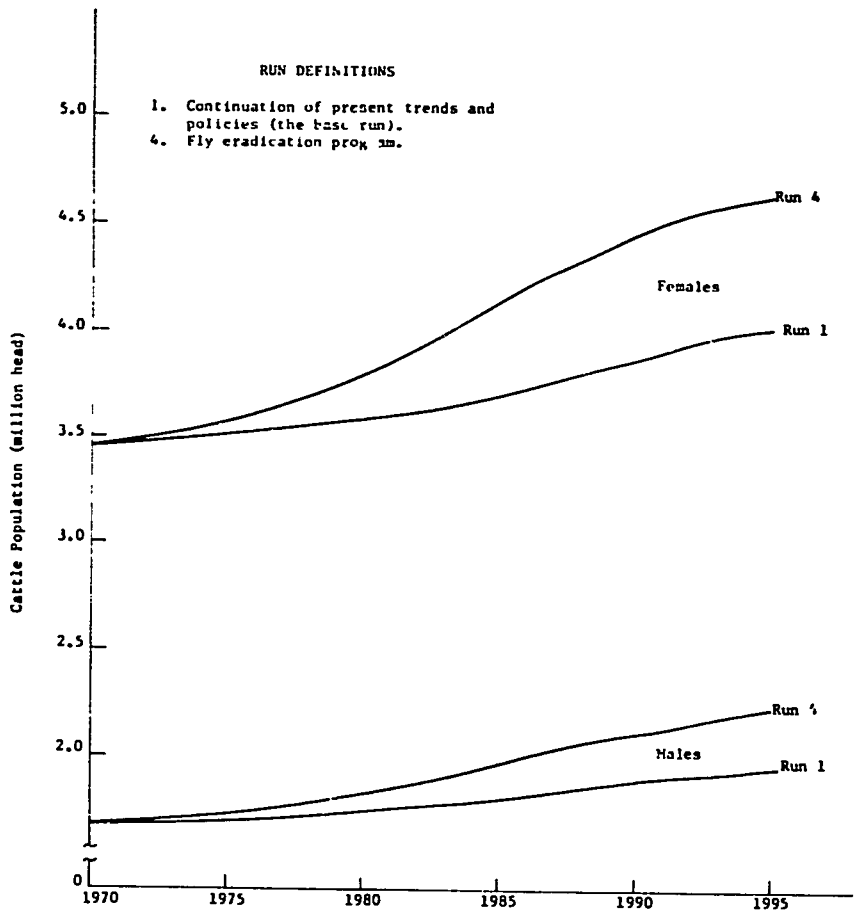

Figure 9.9. Cattle population of males and females in northern Nigeria, 1970-95, with and without a fly eradication program.

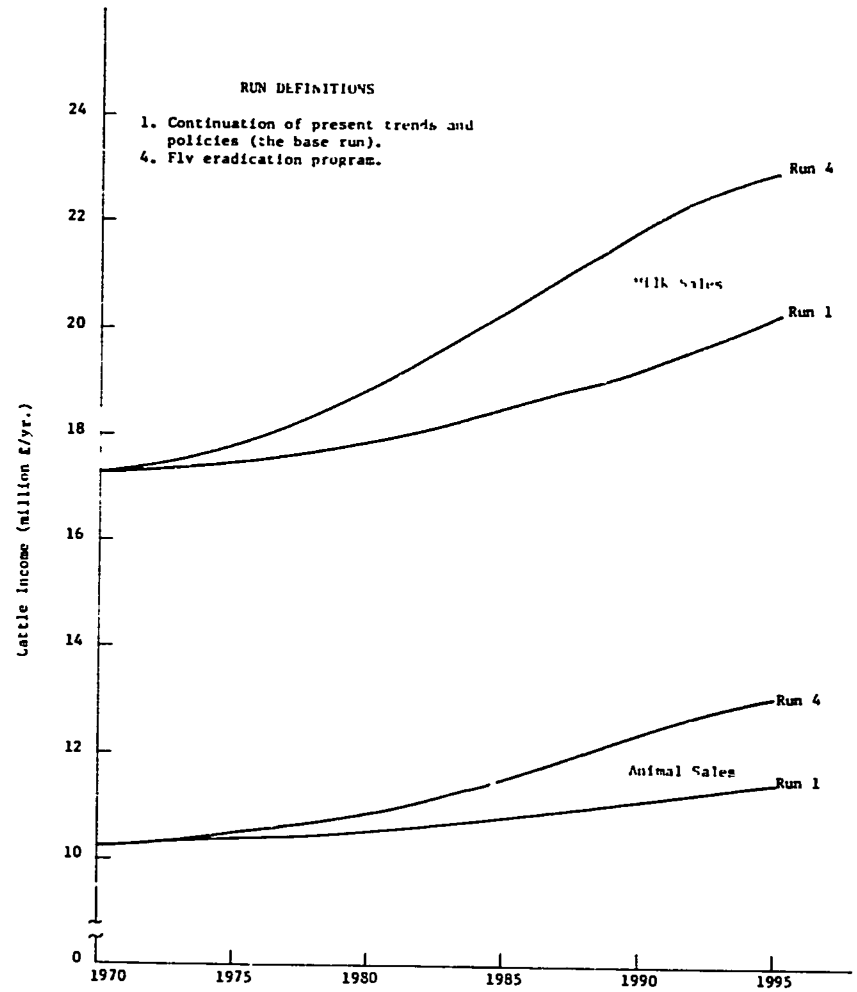

Figure 9.10. Cattle income from animal sales and milk in northern Nigeria, 1970-95, with and without a fly eradication program.

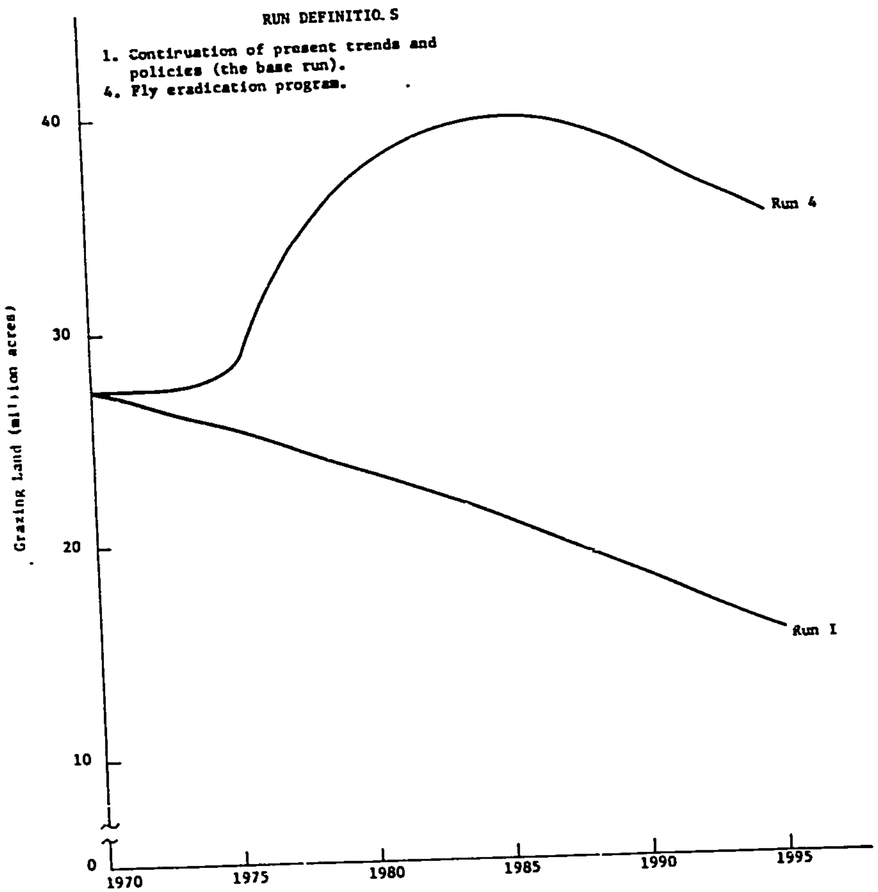

Figure 9.11. Fly-free grazing land in northern Nigeria, 1970-95, with and without a fly eradication program.

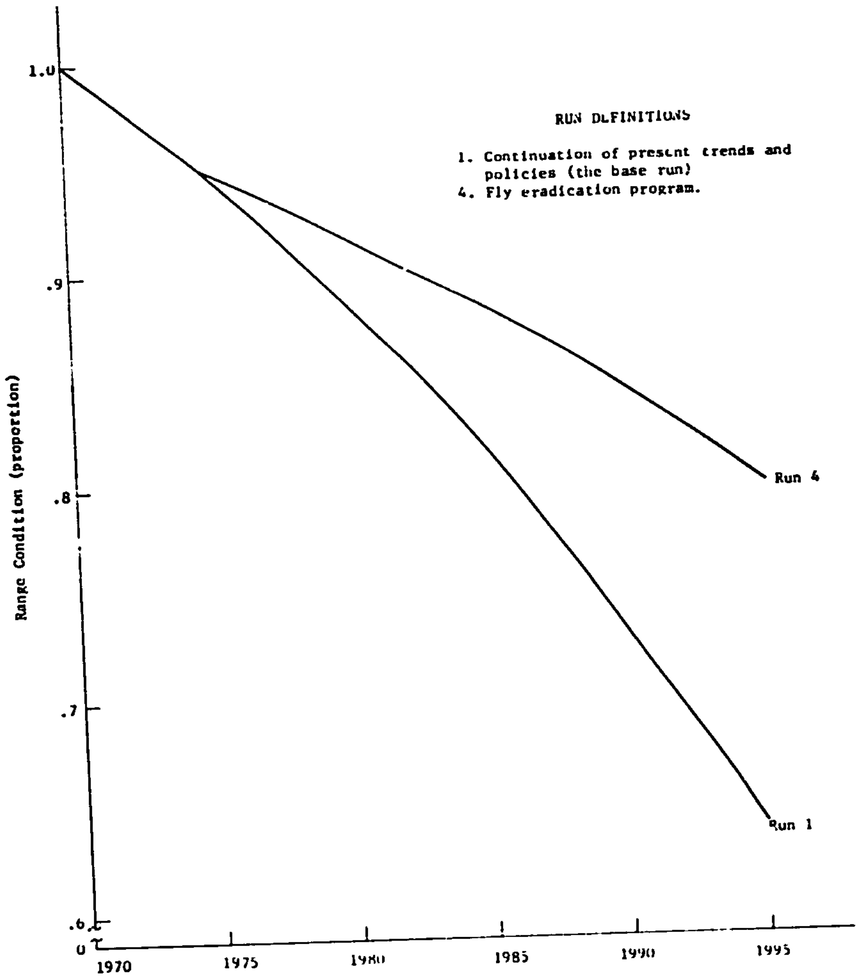

Figure 9.12. Range condition index (the ratio of range land grass yields at a point in time to those yields at the initial time, 1970) in northern Nigeria, 1970-95, with and without a fly eradication program.

The amount of fly-free grazing land experiences a dramatic increase from 1975 to 1985, as a direct result of the eradication program (Figure 9.11). After 1985, however, grazing land starts to decline at about the same rate as in Run 1, due to the expansion of crop lands. Similarly, the decline in range condition due to overgrazing (Figure 9.12) is slowed substantially as new areas are opened up and grazing pressure eases. By 1995, the cattle population is grazing even these new areas to capacity, and the range condition continues to decline at approximately the same rate as in the base run.

The conclusion to be drawn is that the fly eradication program has merely "bought time." The deterioration of overgrazed ranges has been delayed, not halted (much less reversed). The loss of grazing land to crops continues in Run 4 at approximately the same rate as in Run 1. The animal population growth rate (and hence the growth in beef and milk supplies) is the same after the eradication program as before.

This is not to say there shouldn't be a fly eradication program. This program does have substantial short run results, and the time gained by it could be used to carry out programs which will have more long-lasting results. Indeed, other programs, such as grazing reserves, might not even be feasible without the prior elimination of the tsetse fly.

Policy Runs Related to Agriculture in the Northern Region

The set of runs which investigates the consequences of policies and programs relevant to northern Nigeria includes Runs 1, 2, 3, 5, 6 and 7 as defined above and in Table 9.2. Briefly, Run 1 projects present trends and policies (the base run); Run 2 cuts off marketing board and export taxes; Run 3 phases out marketing board and export taxes; Run 5 implements production campaigns in cotton and groundnuts; Run 6 implements a campaign to modernize food grains production, and Run 7 examines production campaigns in all three commodities--cotton, groundnuts and food grains.

The time paths of selected performance variables between 1970 and 1995, under each of the alternative policies outlined above, are shown in the following figures:

Figure	Effect of alternative policies on:
9.13	Total value added in the North
9.14	Foreign exchange from northern agricultural exports
9.15	Total marketing board net revenues from northern commodities
9.16	Disposable income per agricultural worker in the North
9.17	Market price of food staples in the North
9.18	Caloric consumption of staples per capita of the northern nonagricultural population

As expected, the elimination of taxes stimulates agricultural production and incomes. Value added in agriculture improves slightly over the base run (Figure 9.13), as do exports (Figure 9.14).5/ The more immediate stimulus of cutting off taxes (Run 2)

5/ The large negative foreign exchange shown in Figure 9.14 is due primarily to projected import demands of the textile industry being charged to cotton exports. In addition, about 10 to 20 percent of the indicated imports is beef for consumption.

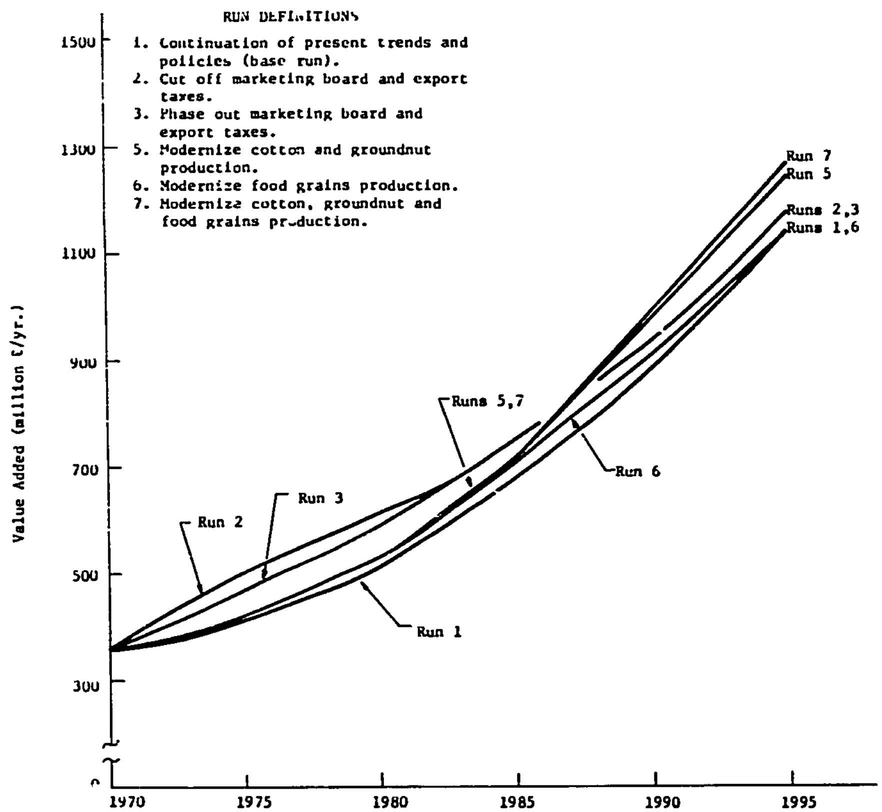

Figure 9.13. Total value added in agriculture in northern Nigeria, 1970-95, under various policies.

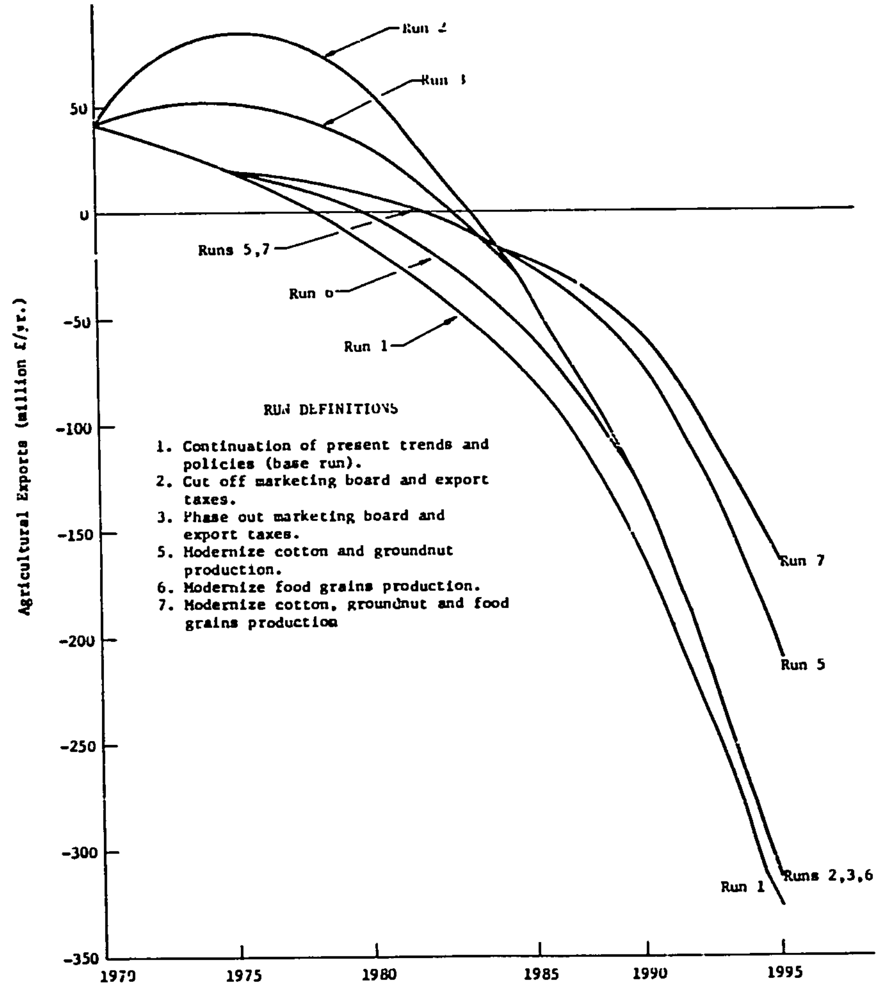

Figure 9.14. Foreign exchange from agricultural exports from northern Nigeria (including imports of cotton and beef), 1970-95, under various policies.

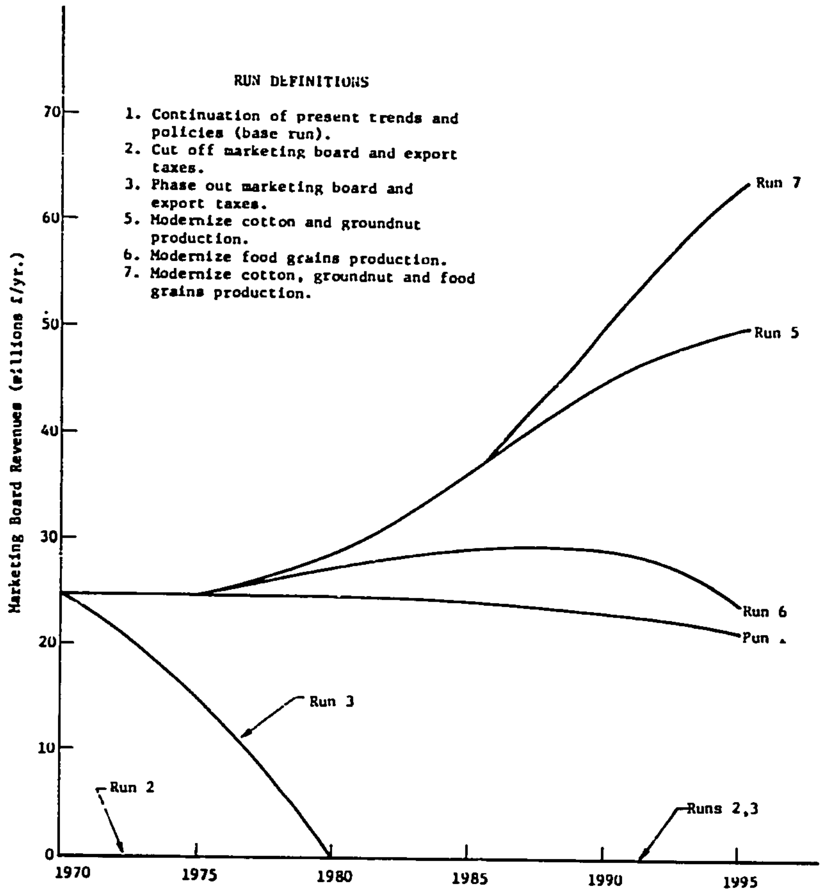

Figure 9.15. Total marketing board net revenues from commodities grown in northern Nigeria, 1970-95, under various policies.

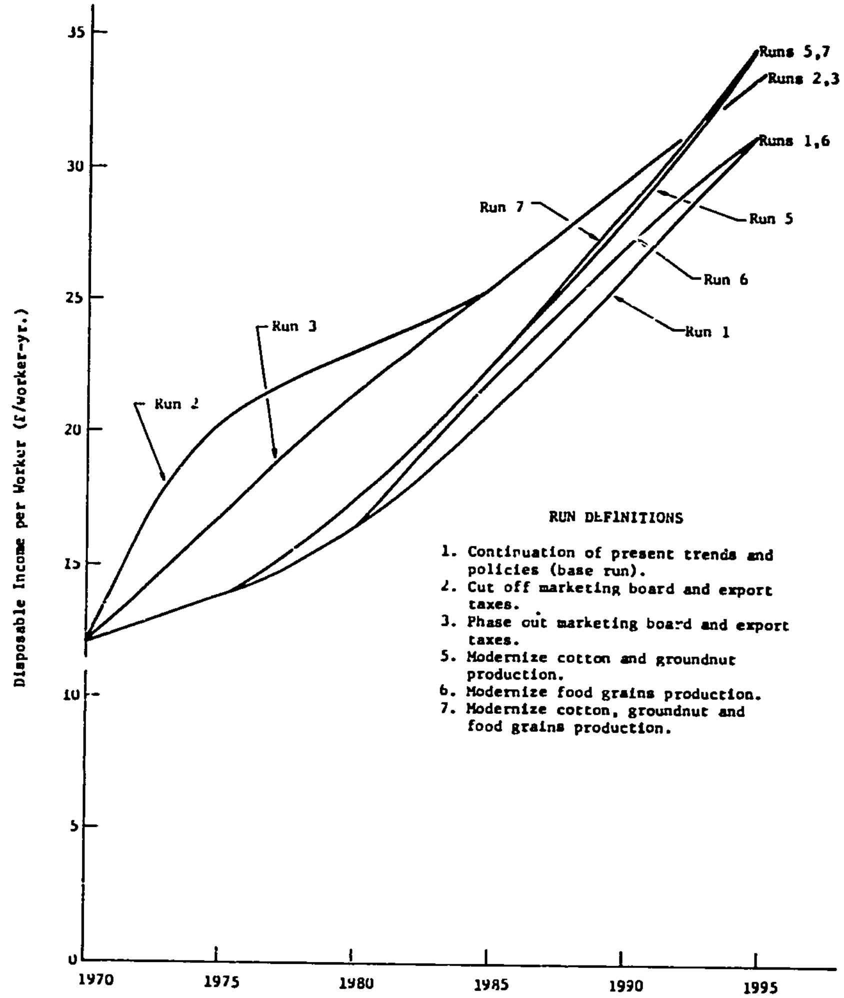

Figure 9.16. Disposable income per agricultural worker in northern Nigeria, 1970-95, under various policies.

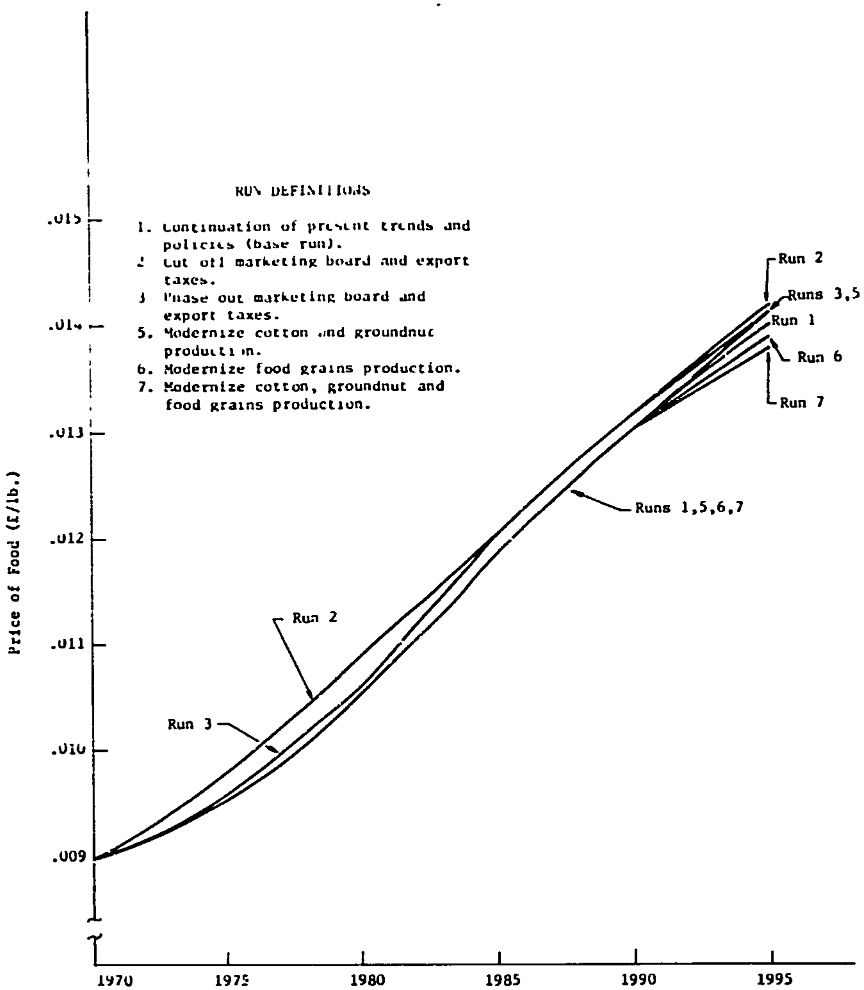

Figure 9.17. Market price of food staple in northern Nigeria, 1970-95, under various policies.

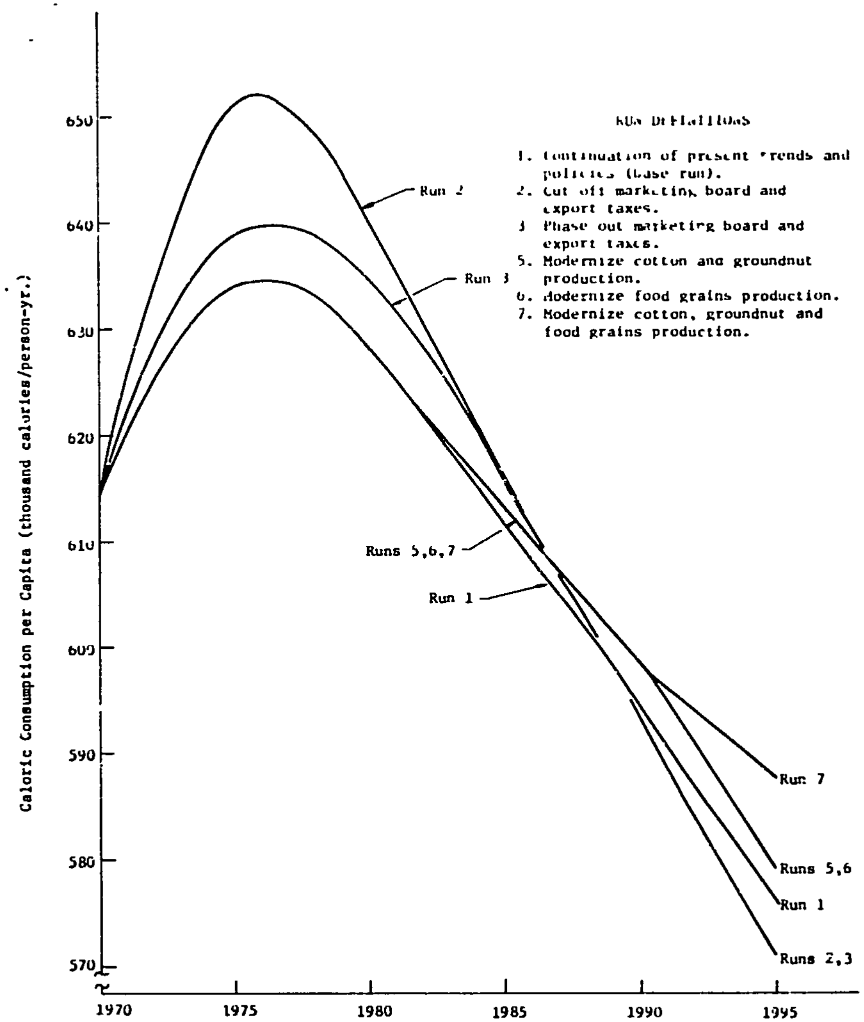

Figure 9.18. Caloric consumption of staples per capita of the nonagricultural population in northern Nigeria, 1970-95, under various policies.

initially causes higher exports and value added than phasing out taxes (Run 3), but also a slightly higher food price (Figure 9.17) for the nonagricultural population. Disposable agricultural worker incomes (Figure 9.15)6/ markedly increased over the base run, due in part to the higher producer prices for cash crops and to slightly higher food prices.7/

The major contributor to increased incomes, however, is the greatly increased (over the base run) cash food sales to the South to meet the higher agricultural and nonagricultural demands for food. Southern agricultural cash food demands increase as the agricultural sector reduces its food crop acreage in response to higher cash incomes resulting from the export crop tax reductions. In addition, southern nonagricultural food demands rise due to the rise in nonagricultural income resulting from the greater demands for nonagricultural goods and services generated by the increased agricultural income (called multiplier effect below).

Runs 2 and 3 have similar long-run results. After 1980, when marketing board and export taxes are zero in either policy situation, food consumption by the nonagricultural population (Figure 9.18) shows a substantial rise, as the increased agricultural incomes from Runs 2 and 3 begin to have their multiplier effects on nonagricultural incomes. Later, higher food prices cause nonagricultural food consumption to approach the same level as in the base run.

Figure 9.18 indicates steadily falling nonagricultural food consumption in all runs (as do Figures 9.25 and 9.35 below). These results must be interpreted with caution. They represent only staple food consumption, and do not incorporate other sources of nutrition, such as fish, meat, fruits and vegetables. As nonagricultural incomes rise, we might expect to see an increasing substitution of these items for the staples treated in the model.

The modernization of cotton and groundnut production (Run 5) substantially improves the performance of all the variables observed, compared to both the base run and the runs eliminating taxes. Foreign exchange increases most (Figure 9.14), about 30 percent over Run 1. Since food crops, rather than export crops, dominate northern agricultural production, other variables, such as value added (Figure 9.13), income (Figure 9.16) and, hence, food consumption (Figure 9.18), show a less dramatic increase. Marketing board revenues (Figure 9.15) show a 150 percent increase by 1995.

Run 6 examines a program to modernize food grains production. Indeed, foreign exchange and marketing board revenues do pick up (over the base run) as land and labor are released for cash crop production. The difference is less pronounced at the end of the run (1995) than earlier in the simulated time period, as the initial reduction in total food land is gradually reversed to meet the subsistence demands of the expanding agricultural population. Throughout the time period 1970-95, exports and marketing board revenues in Run 6 are below those of Run 5, where cash crop production is directly transformed. This can be explained by the slower diffusion of food modernization (compared to cash crop modernization diffusion), which is

6/ *Disposable income in Figure 9.15 (and Figure 9.23) includes wages earned, but is net of agricultural sector debt service and interest.*

7/ *Food accounts for about 90 percent of agricultural value added in the North.*

built into the model. A larger promotion effort (budget) would stimulate a quicker response to food modernization and, hence, a larger effect on cash crop production.

In Run 7, promotion efforts are conducted in cotton, groundnuts and food grains simultaneously. Most output variables compound the increases of Runs 5 and 6 over the base run. The results in Run 7 are more than the mere addition of these increases. Marketing board revenues (Figure 9.15) provide a striking example of this. Run 7 revenues in 1995 are 200 percent greater than Run 1 while revenues in Runs 5 and 6 are 150 percent and 15 percent greater, respectively. This is due to the fact that cash crop production, which has expanded onto former food land as a consequence of food modernization, is itself modernized in Run 7, further augmenting the positive results of Run 6. In addition, and more significant in the long run, the modernization of food in conjunction with cotton and groundnuts allows more timely planting of the cash crops, resulting in even higher yields than would otherwise be obtained from the modern varieties.

Food prices are lower in Run 7 than in any other run. This effect is more than offset, however, by the increased productivity of food, so that value added and income are slightly higher in Run 7 than Run 5. The lower food prices coupled with increased nonagricultural income result in higher nonagricultural food consumption.

Policy Runs Related to Agriculture in the Southern Region

The set of runs which investigates the consequences of policies and programs relevant to southern Nigeria includes Runs 1, 2, 3, 8, 9, and 10 as defined earlier and in Table 9.2. Briefly, Run 1 projects present trends and policies (the base run); Run 2 cuts off marketing board and export taxes; Run 3 phases out these taxes; Run 8 implements production campaigns in all three perennial commodities (cocoa, palm and rubber); Run 9 implements production campaigns in cocoa and palm only, and Run 10 implements the same programs as Run 8, simultaneously with investments to modernize and transform palm and rubber processing capacities (to Stork presses and crumb factories, respectively). Run 10 also assumes that the domestic demand for crumb rubber increases gradually to 50 percent of production.

The time paths of selected performance variables between 1970 and 1995 under each of the alternative policies outlined above are shown in the following figures:

Figure	Effect of alternative policies on:
9.19	Total value added in agriculture in the South
9.20	Foreign exchange from southern agricultural exports
9.21	Total marketing board net revenues from southern commodities
9.22	Foreign exchange from palm oil exports
9.23	Disposable income per agricultural worker in the South
9.24	Market price of food staples in the South
9.25	Caloric consumption of staples per capita of the southern nonagricultural population

The most striking observation that can be made about Runs 2 and 3 (cutting off and phasing out taxes) is not that the long run results are virtually identical, for taxes are eventually zero in both cases. Nor is it that incomes, value added, exports, etc.

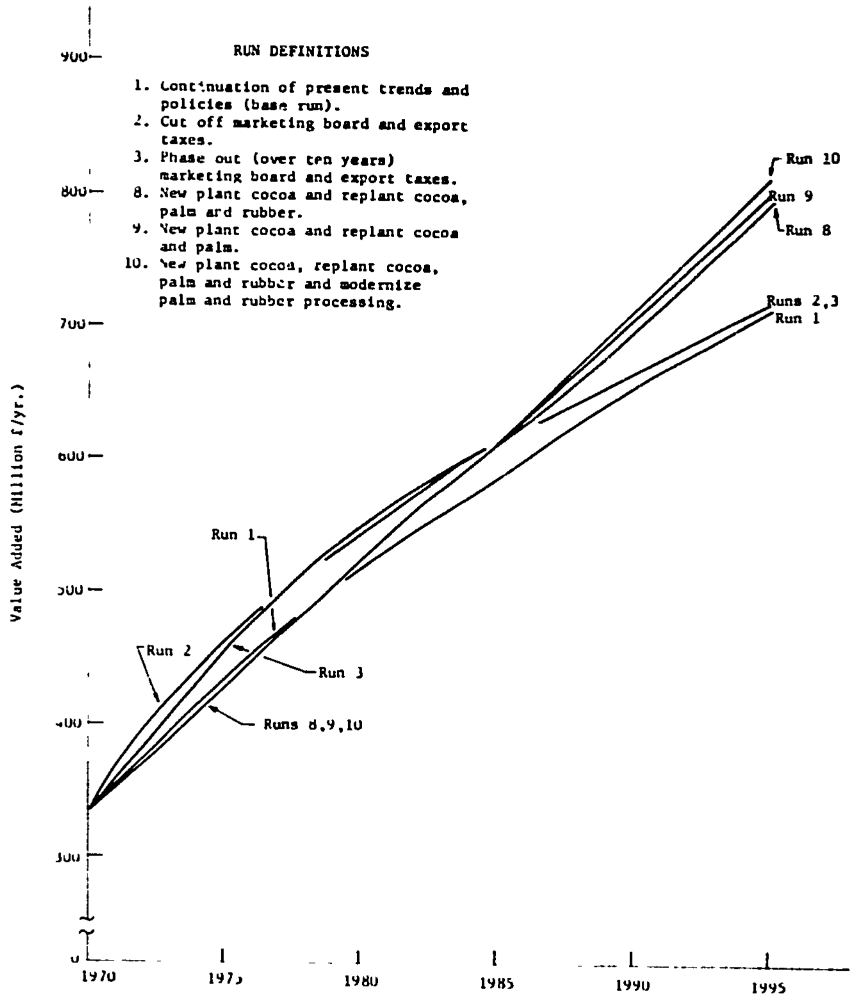

Figure 9.19. Total value added in agriculture in southern Nigeria, 1970-95, under various policies.

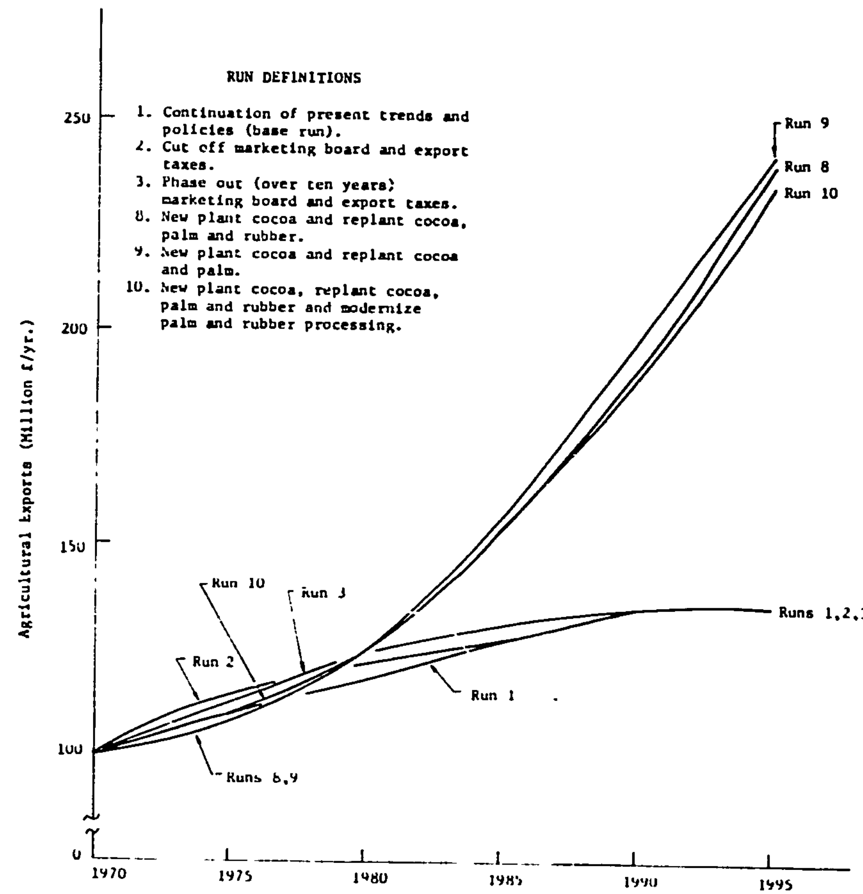

Figure 9.20. Foreign exchange from agricultural exports from southern Nigeria, 1970-95, under various policies.

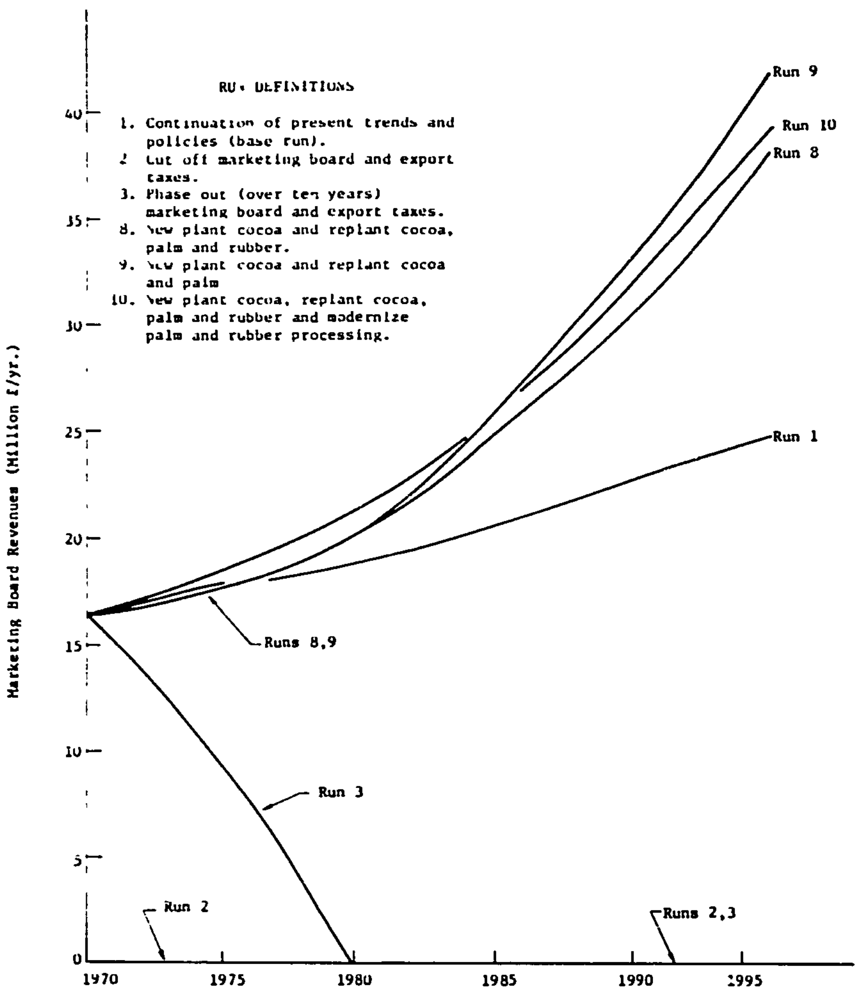

Figure 9.21. Total marketing board net revenues from export commodities grown in southern Nigeria, 1970-95, under various policies.

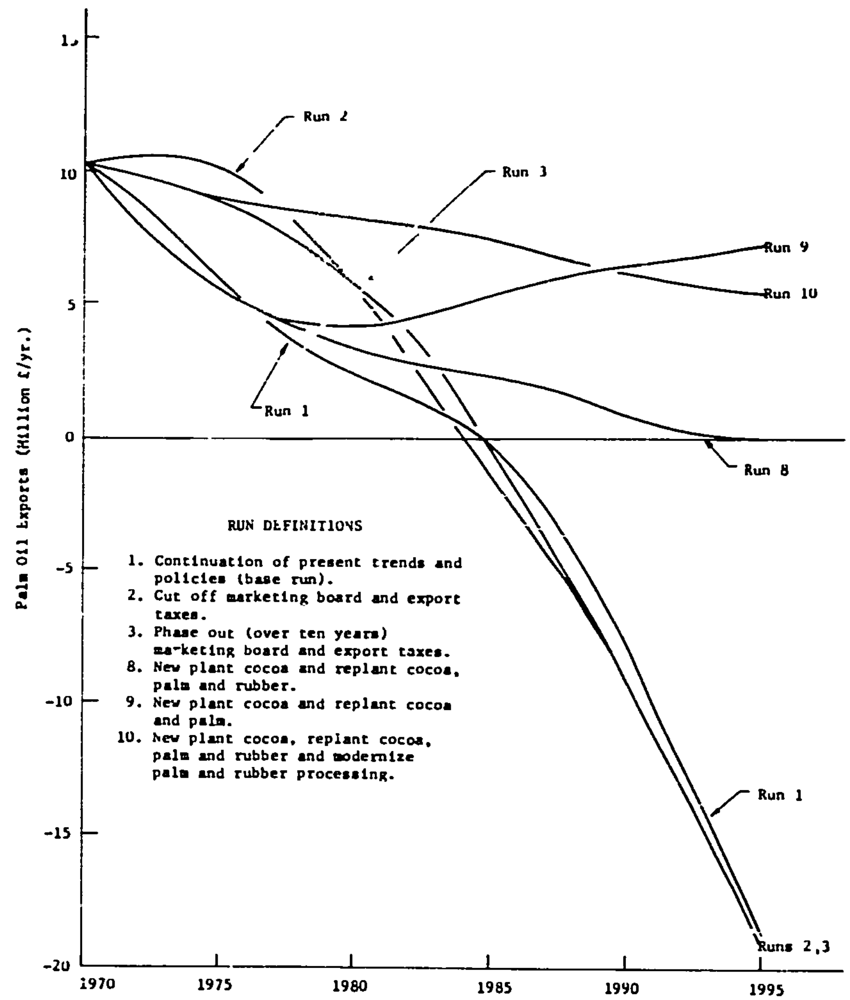

Figure 9.22. Foreign exchange from Nigerian palm oil exports, 1970-95, under various policies.

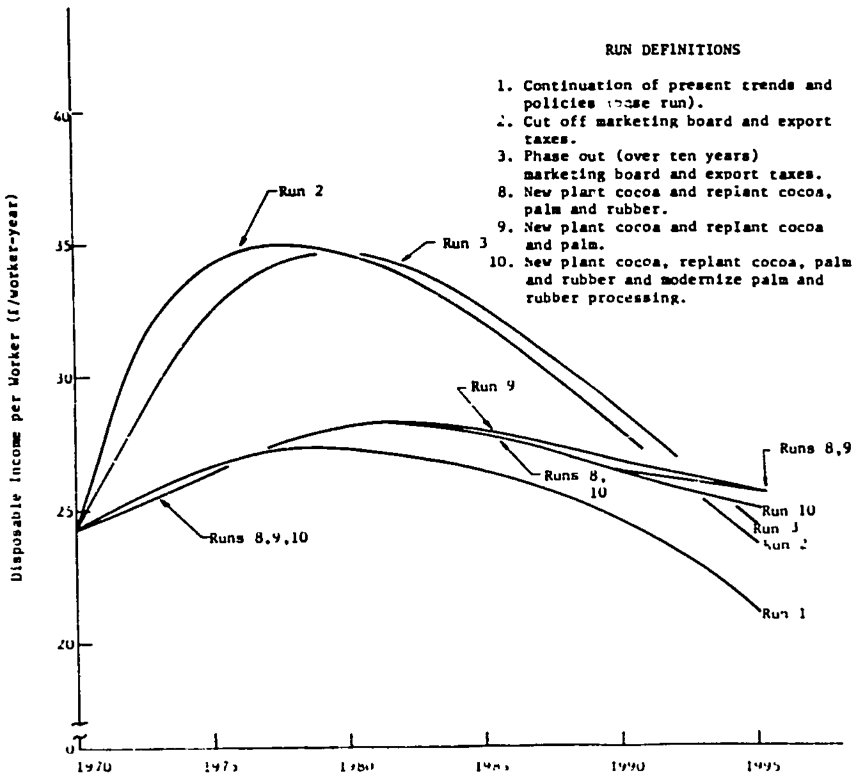

Figure 9.23. Real disposable income per agricultural worker in southern Nigeria, 1970-95, under various policies.

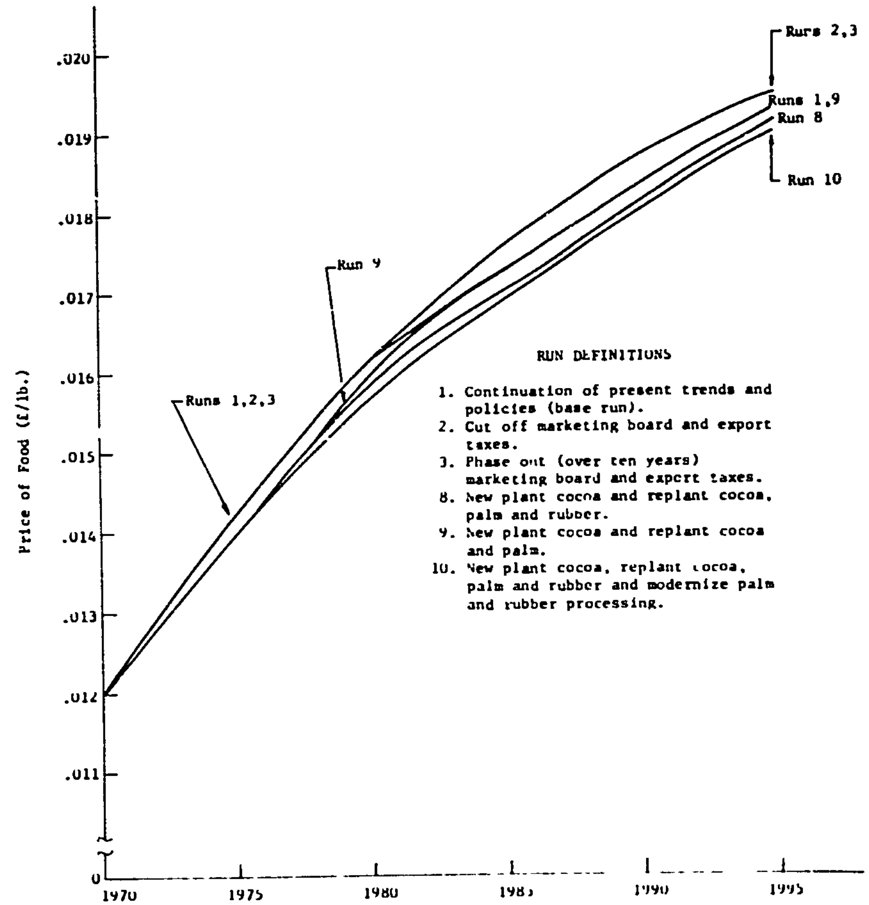

Figure 9.24. Market price of food staples in southern Nigeria, 1970-95, under various policies.

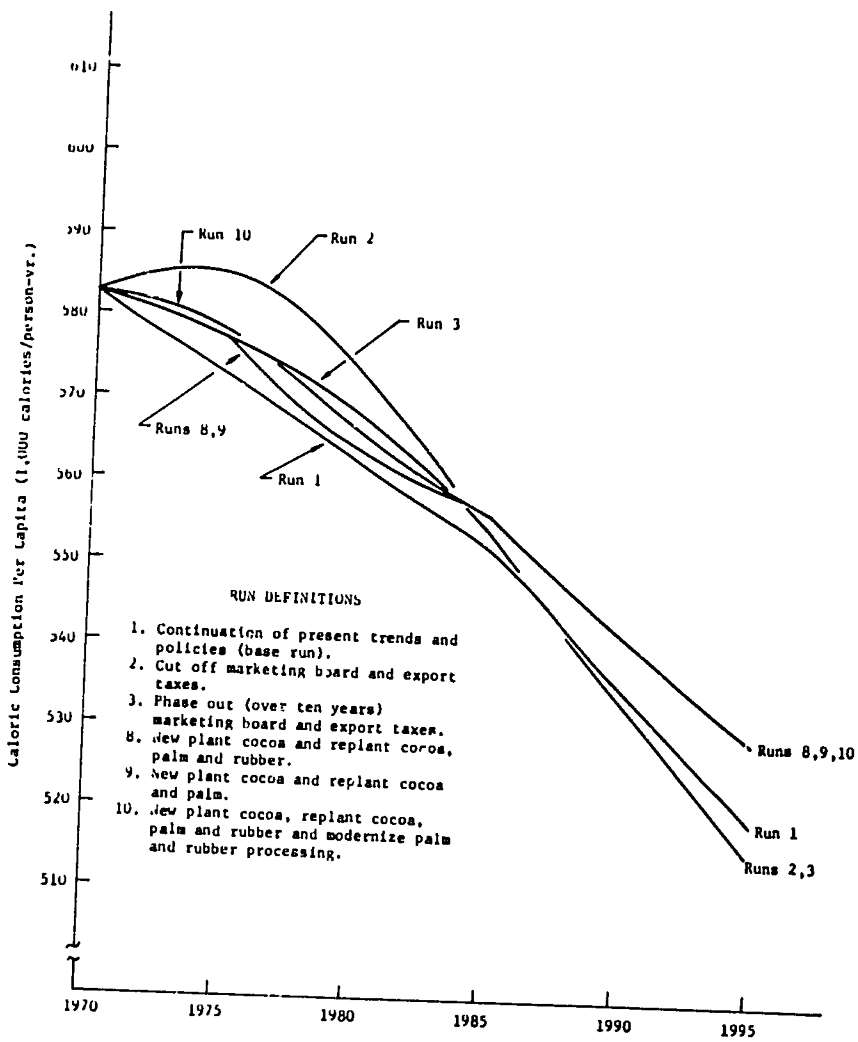

Figure 9.25. Caloric consumption of staples per capita of the nonagricultural population in southern Nigeria, 1970-95, under various policies.

are initially higher than the other runs and consistently higher than the base run. The reduction in taxes represents an immediate increase in producer prices, whereas there is a delay involved before the perennial modernization programs show results. This delay is due to the natural gestation and maturation lags of the perennials and the longer lags before the innovations are diffused beyond the direct promotion results. The most striking observation concerning the behavior shown in Runs 2 and 3 is that value added, exports and income (Figures 9.19, 9.20 and 9.23) are relatively higher initially in Run 2 than in Run 3; later in the simulated time period (after about 1978), they are relatively higher in Run 3 than in Run 2 and finally approach the same steady state levels in both runs. Run 2 should indeed have higher results initially since producer price increases are immediate. The short term supply (harvest) response is sharp initially, then tapers off, ultimately returning to normal levels as farmers gradually come to regard the higher prices as "normal." Exports begin to increase again after 1980 (Figure 9.20), as the long term supply (planting) response to the higher prices becomes increasingly dominant, finally tapering off again after acreage expands to its limit (as in the base run) and production from aging traditional trees falls.

In Run 3, prices rise steadily over a 10-year period while taxes are phased out. Thus, the harvest response is lower than in Run 2. However, it lasts longer, since the new price (achieved when taxes have finally been eliminated) is not seen as "normal" by the farmers until later. Therefore, while exports in Run 2 taper off, the harvest and planting responses re-inforce each other in Run 3. Eventually, the acreage limits are reached, the natural aging process decreases yields, and the long-run results of Runs 2 and 3 are virtually the same (Figures 9.19, 9.20, 9.22, 9.23).

Although long-run exports, when taxes are removed, are virtually the same as in the base run (due to capacity limits and aging traditional trees), the higher prices keep long-run value added and income per worker (Figures 9.19 and 9.23) higher than the base run. Per worker income falls during the latter part of the runs because the labor force is growing faster than income.

The increased agricultural incomes, via multiplier effects on nonagricultural incomes, cause a higher consumption (in Runs 2 and 3 than in Run 1) of staple calories by the nonagricultural population through most of the simulated time period (Figure 9.25). As incomes stabilize in the long run, however, the higher food prices associated with Runs 2 and 3 result in lower nonagricultural staple food consumption.

Comparing Runs 8 and 10 (production campaigns in the three major perennial commodities without and with modernization of palm and rubber processing), some interesting observations can be made. Value added (Figure 9.19) and marketing board revenues (Figure 9.21) are higher in Run 10 than in Run 8 due to the increased technical efficiency of oil palm and rubber processing facilities. While palm oil exports are also substantially improved (Figure 9.22), total exports (Figure 9.20) are lower due to the assumption in Run 10 that the domestic demand for rubber increases to 50 percent of production over a 15-year period, thus reducing rubber exports (which don't pass through a marketing board--thus not diminishing marketing board revenues). Indeed, exports <u>are</u> initially higher in Run 10 while domestic rubber demand is still low.

In spite of this increased production, incomes in Run 10 are <u>lower</u> than in Run 8 (Figure 9.23). The reason is that palm oil processing with the Stork hydraulic presses, while <u>technically</u> more efficient, i.e., more oil is extracted per pound of fruit, is <u>economically</u> inefficient. The increased processing costs outweigh the revenue from increased production, thus making palm processing unprofitable.[8] The centralized crumb rubber factories, on the other hand, prove to be substantially more efficient, economically as well as technically, than the traditional sheet-making facilities operated on the village level.

8/ *The transformation of processing takes place in the model regardless of its profitability. It is carried out solely by an exogenous (policy) investment. The model's rudimentary processing component would have to be somewhat expanded to more realistically simulate investment decisions.*

Run 9 was an experiment to investigate the consequences of increasing the palm replanting effort at the expense of rubber in the crop sector where the two perennials compete. Indeed, palm oil exports do improve substantially over Run 8 (Figure 9.22). Value added and total exports are also higher in spite of the still traditional rubber production.

It is interesting to note that value added, exports, marketing board revenues and income per worker are all lower in Runs 8 and 9 than in the base run for about the first six to eight years of the simulated time period (1976-78) before rising to substantially improved levels. This is caused by the replanting programs removing trees from production and the gestation lag which occurs before the new trees come into production.

Nonagricultural food consumption is higher in Runs 8, 9 and 10 than in the other runs (Figure 9.25) due to the multiplier effects of increased agricultural incomes (Figure 9.23) on nonagricultural incomes and slightly lower food prices (Figure 9.24).

Policy Runs Related to Agriculture for Both the Northern and Southern Regions

The fourth set of runs, Runs 1, 11, 12, 13, 14 and 15, examines the results of agricultural development policies and programs at the national level. Briefly, Run 1 projects present trends and policies (the base run); Run 11 implements production campaigns in cotton, groundnuts, food grains, cocoa, palm and rubber; Run 12 implements a program to modernize food roots in the Middle Belt in addition to the above programs; Run 13 investigates the effects of, in addition to the programs of Run 11, the diffusion of a further doubling of food grain yields beginning after 1980; Run 14 implements the programs of Run 11 with a cut-off of taxes; and Run 15 does the same as Run 14, except with a phase out of taxes.

The time paths of selected performance variables between 1970 and 1995 under each of the alternative policies outlined above are shown in the following figures:

Figure	Effect of alternative policies on:
9.26	Total value added in northern agriculture
9.27	Total value added in southern agriculture
9.28	Foreign exchange from northern agricultural exports
9.29	Foreign exchange from southern agricultural exports
9.30	Total marketing board net revenues from northern and southern commodities
9.31	Gross domestic product
9.32	Total exports
9.33	Total imports
9.34	Market price of food staples in the North
9.35	Caloric consumption of staples of the southern nonagricultural population

Coupled with the modernization programs, the elimination of marketing board and export taxes substantially enhances the results of the modernization programs in the presence of these taxes. Figures 9.32 and 9.33 indicate that, while both total exports and total imports increase in Runs 14 and 15, compared to Run 11, exports experience a relatively greater rise, leaving Nigeria with a more favorable balance of payments. Similar increases are seen in other variables, such as GDP (assuming market board and export tax revenues are not put to productive use), value added in agriculture and agricultural exports (Figures 9.26 through 9.29 and 9.31).

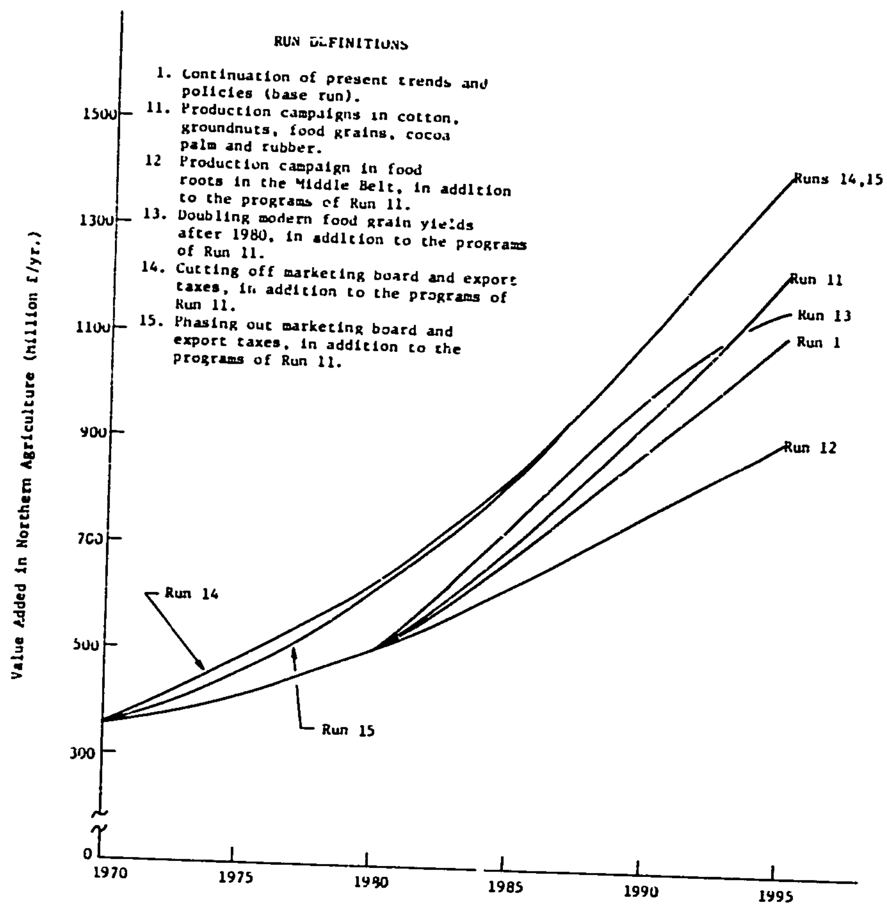

Figure 9.26. Total value added in agriculture in northern Nigeria, 1970-95, under various policies.

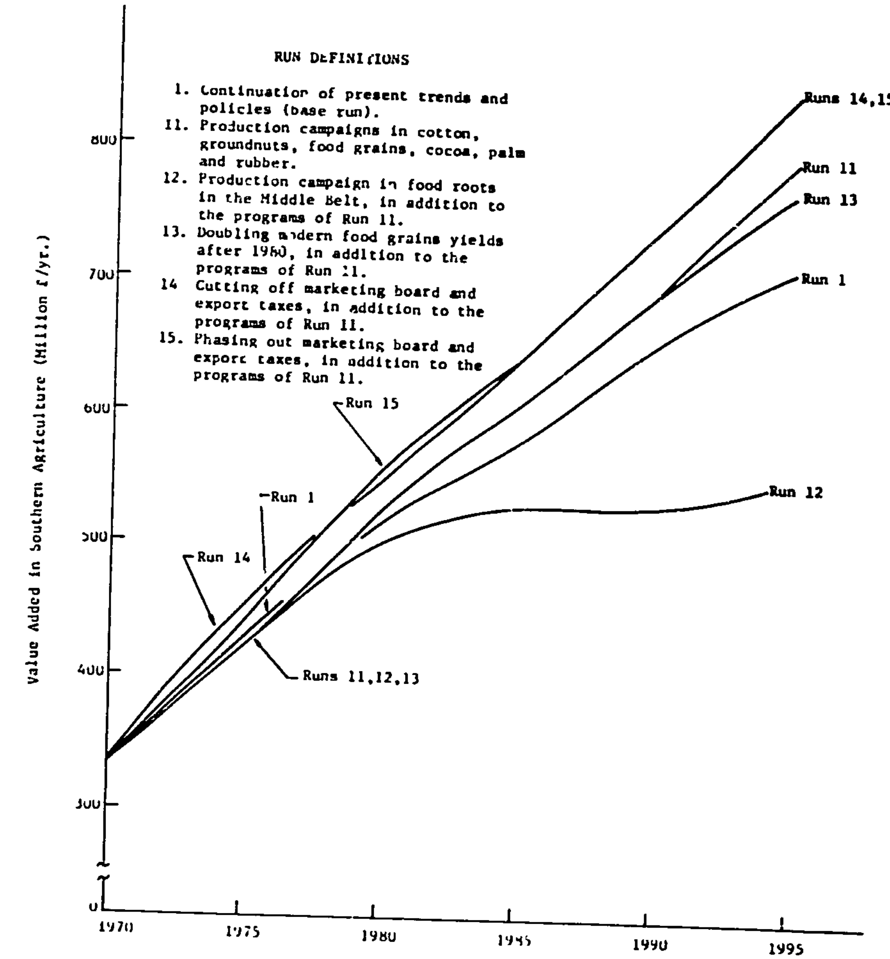

Figure 9.27. Total value added in agriculture in southern Nigeria, 1970-95, under various policies.

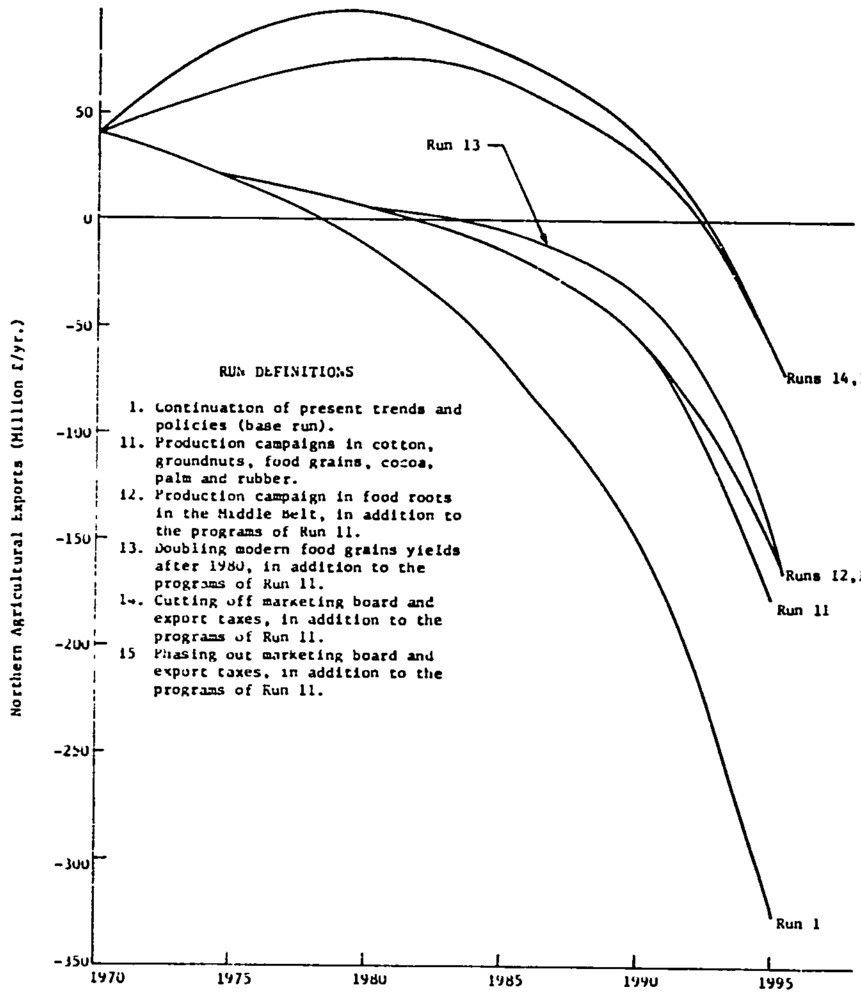

Figure 9.28. Foreign exchange from agricultural exports from northern Nigeria (including imports of cotton and beef), 1970-95, under various policies.

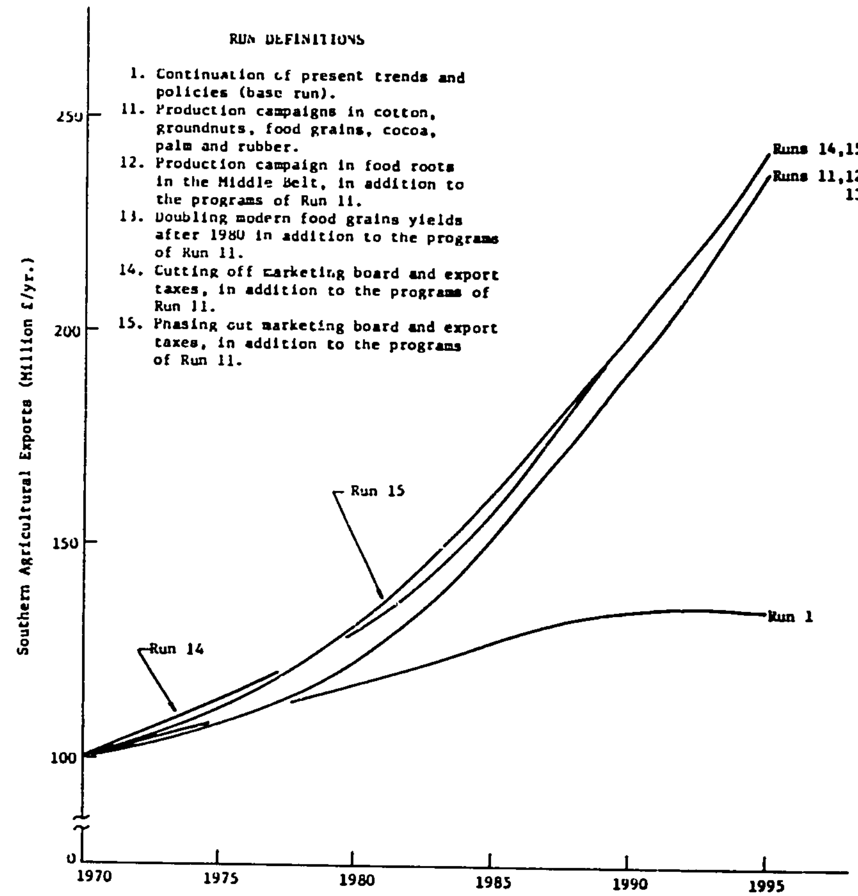

Figure 9.29. Foreign exchange from agricultural exports from southern Nigeria, 1970-95, under various policies.

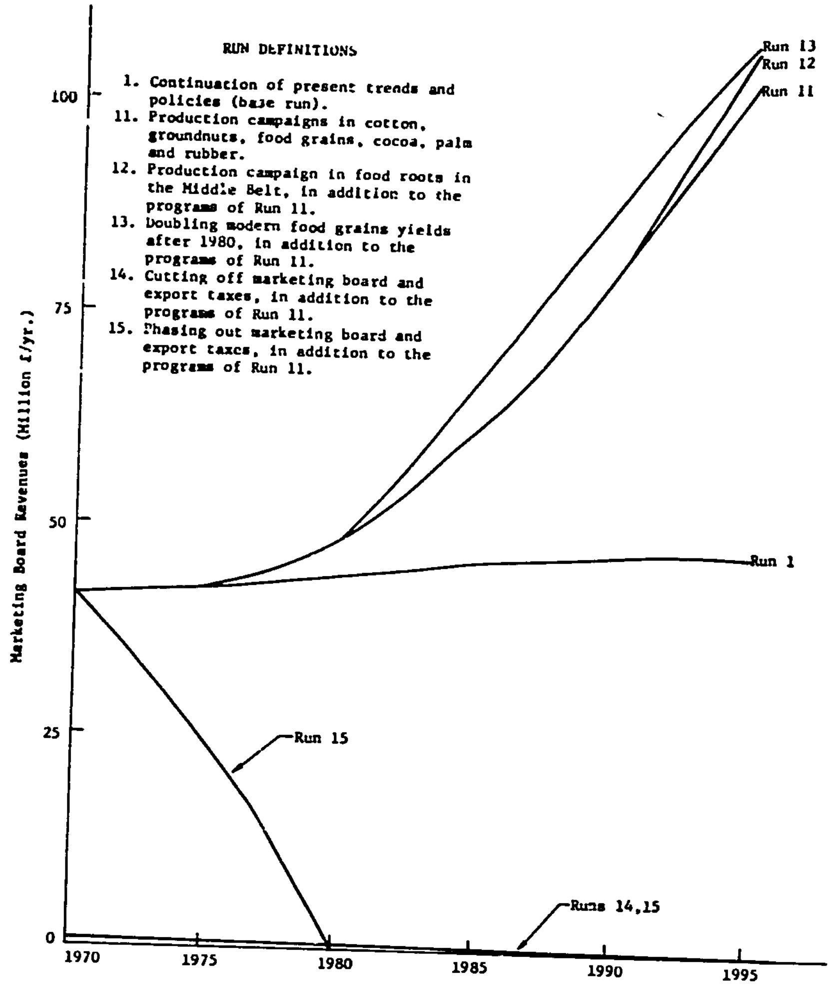

Figure 9.31. Gross domestic product in Nigeria, 1970-95, under various policies.
Note: it is assumed that marketing board and export taxes are not put to productive use.

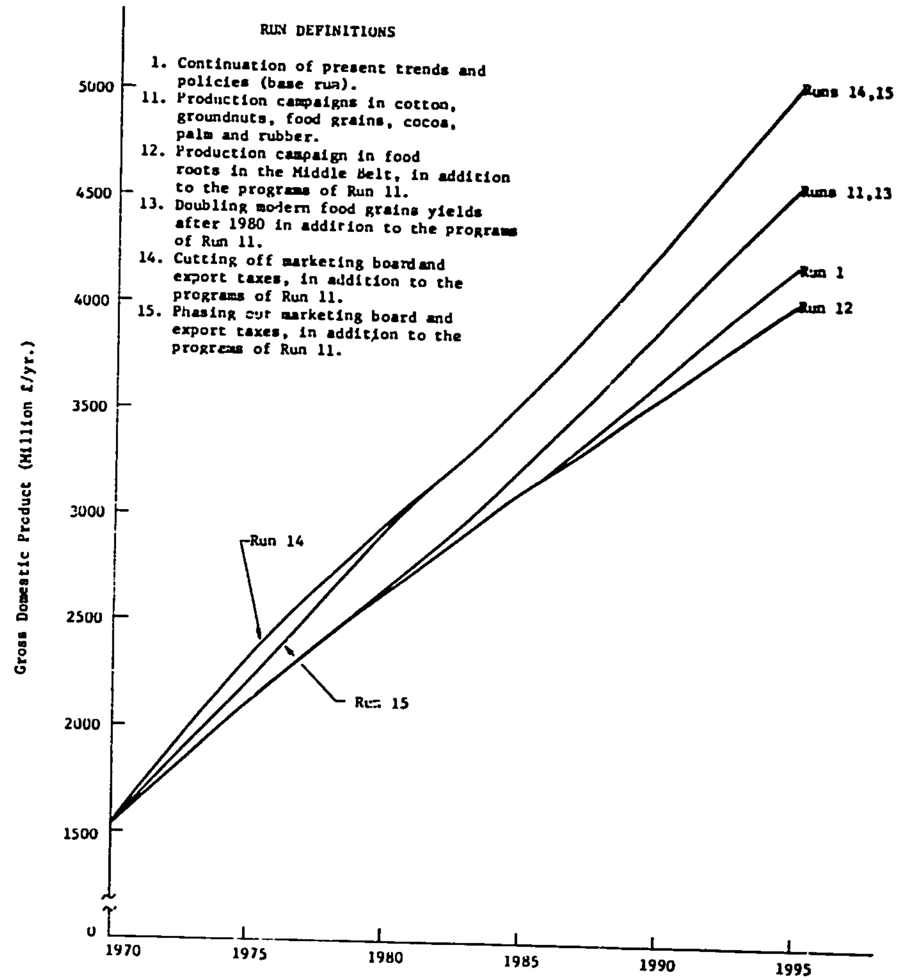

Figure 9.30. Total marketing board net revenues from Nigerian export commodities, 1970-95, under various policies.

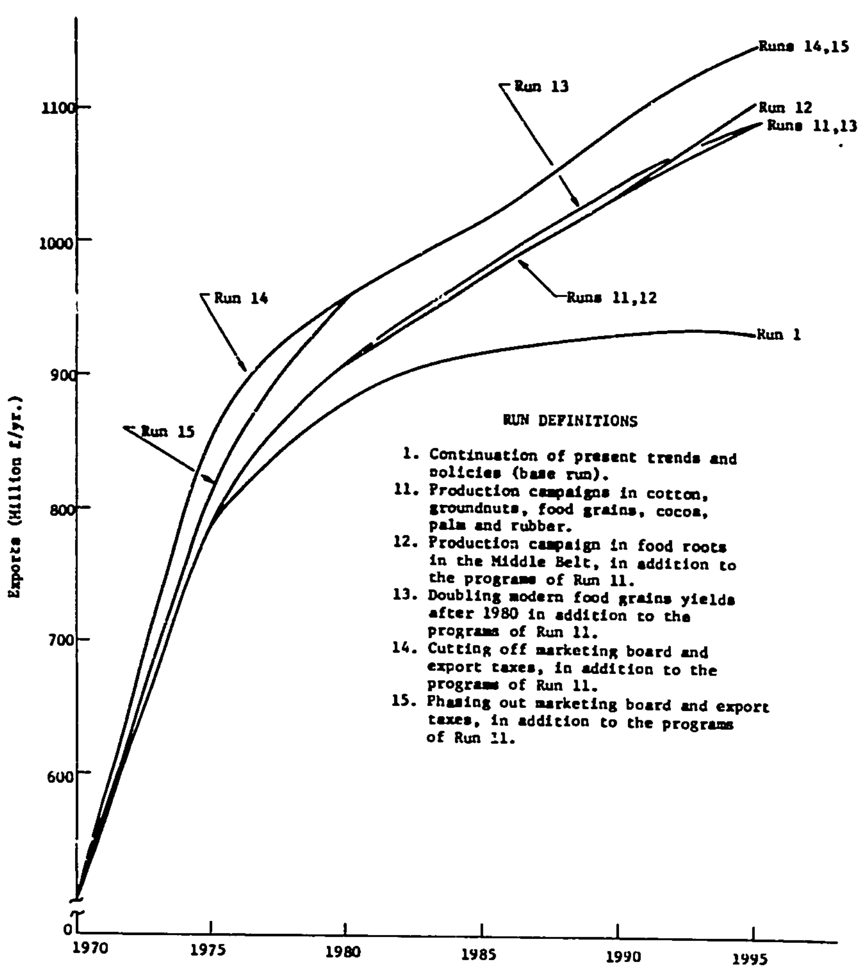

Figure 9.32. Total exports from Nigeria (agricultural and nonagricultural), 1970-95, under various policies.

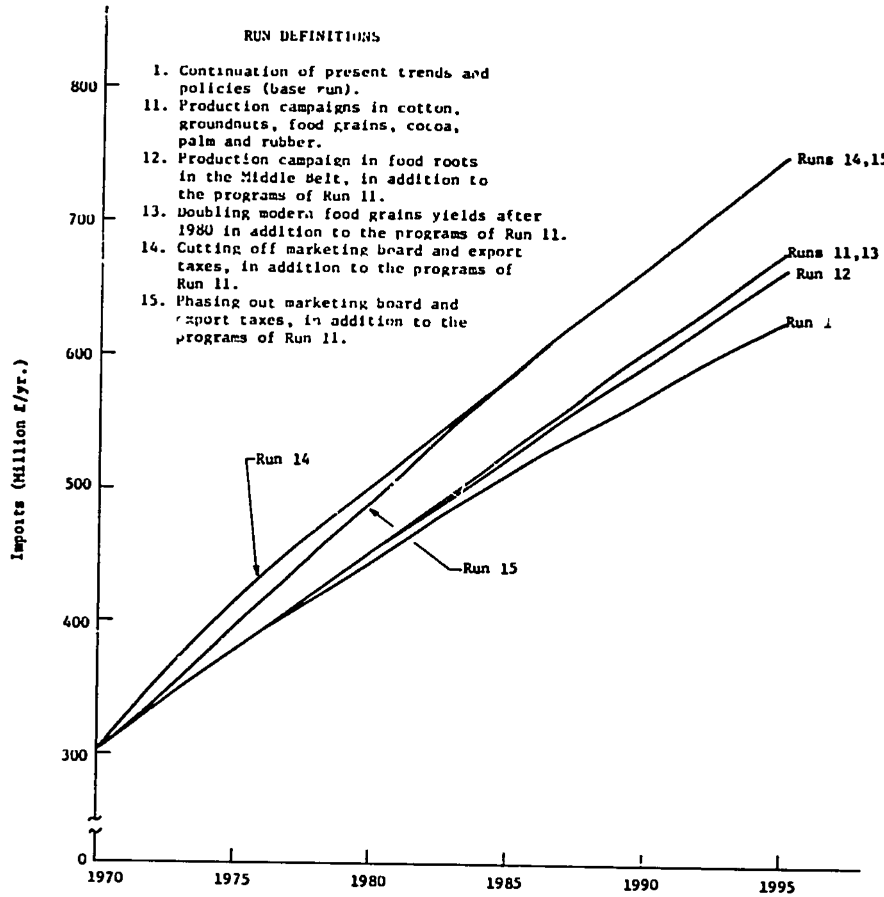

Figure 9.33. Total imports to Nigeria, 1970-95, under various policies.

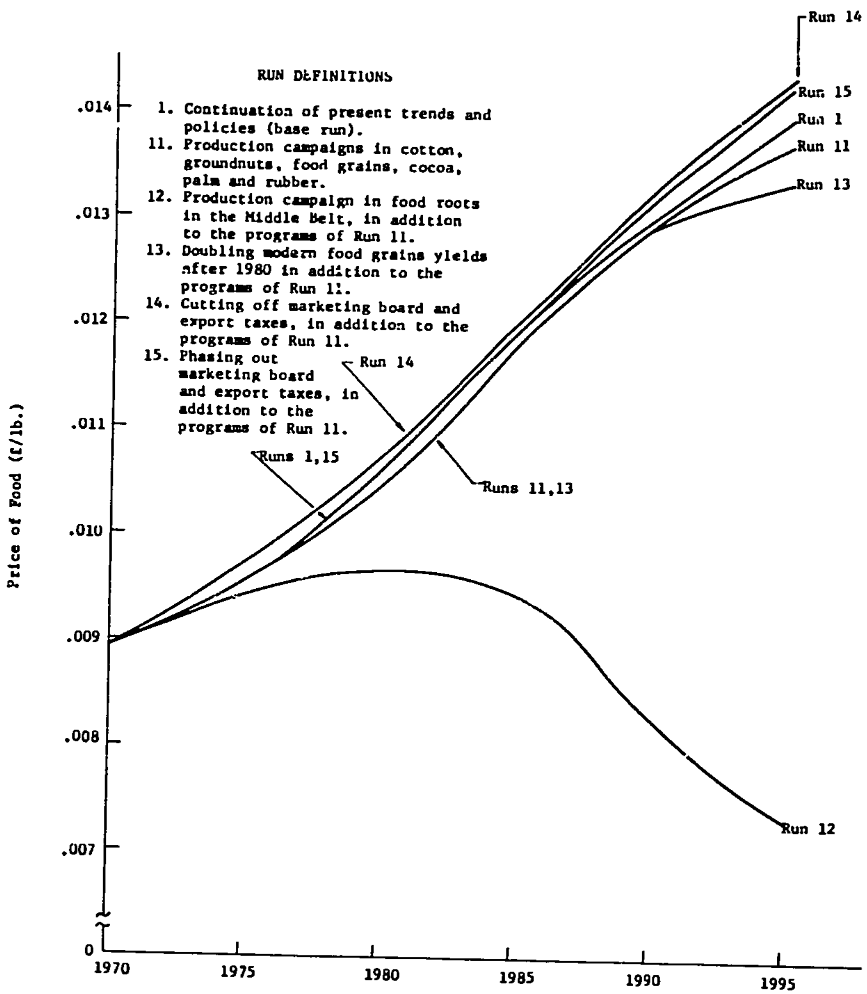

Figure 9.34. Market price of food staples in northern Nigeria, 1970-95, under various policies.

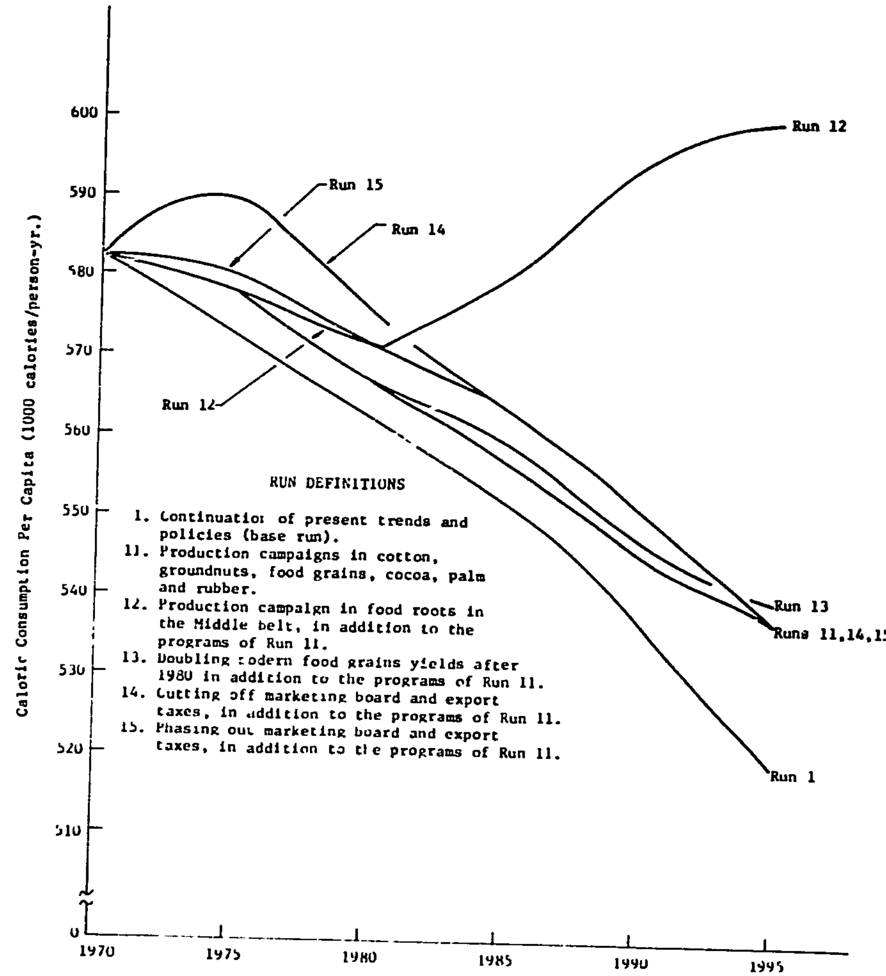

Figure 9.35. Caloric consumption of food staples of the nonagricultural population in southern Nigeria, 1970-95, under various policies.

Nonagricultural food consumption is higher in Runs 11, 14 and 15, with modernization, than in the base run (Figure 9.35). This is due to the multiplier effect of increased agricultural income on nonagricultural income, i.e., increasing agricultural demand for consumer goods from the nonagricultural sector.

Run 12 was an attempt to speculate on the consequences of increased production of food root crops in the Middle Belt (assuming improved technology to be available). The indications are that the South would tend to specialize in exports while importing food from the North. Shipments of food increase about 56 percent by 1995 over Run 11. However, this results in much lower food prices (Figure 9.34), rather than the substitution of perennial production for food production; southern agricultural exports remain virtually the same as Run 11 (Figure 9.29). This can be attributed to the current model's limitations, specifically the one which constrains the transfer of food land to perennial production. Without this restriction, we would see a move to export specialization in the South in the presence of a secure food supply from the North. The lower food prices do lead to a dramatically higher level of food consumption by the nonagricultural population (Figure 9.35).

An interesting observation can be made concerning agricultural value added and GDP (Figures 9.26, 9.27 and 9.31). Such a large proportion of value added and GDP is derived from food production (about 80 percent for agricultural value added and 30 percent for GDP) that these variables at current prices are depressed in Run 11 and (particularly) Run 12, due to lower food prices (Figure 9.34). In "real" terms, i.e., relative to food prices in the base run, Runs 12 and 11 would show even greater improvements over Run 1, with Run 12 probably taking the lead.

Modern food grain yields in the North were gradually doubled in Run 13 over a four to five-year period after 1980, i.e., to five times the current traditional yields, to investigate the consequences of the introduction and diffusion of new technologies expected to be developed during the 1970's. The results show that exports (Figure 9.28) and marketing board revenues (Figure 9.30) do improve substantially over Run 11 after 1980. Value added also increases slightly (Figure 9.26). However, by the end of the simulated time period, the results of Run 13 and Run 11 become quite similar. The initial increase in cash crop acreage, resulting from labor and land freed from subsistence food production, is later reduced as the population continues to expand and more food land is required. Value added in Run 13 (Figure 9.26) eventually falls below that of Run 11 due to the somewhat lower food prices. The effect on southern exports is nil (Figure 9.29), while the lower food prices cause southern value added to fall slightly and nonagricultural food consumption to rise.

Note that value added in the North rises more than twice as fast as in the South (Figures 9.26 and 9.27). This is due to the much more dominant role food plays in northern agriculture. In the base run, food accounts for over 90 percent of value added in the North and only about 75 percent in the South. Rising food prices and steady, or falling export prices, account for the rapid rise in northern value added, compared to the South.

Policy Runs Related to Budget Levels For Production Campaigns

The fifth set, Runs 1, 11, 16 and 17, investigates the relative effects of various levels of production campaign budgets. Run 1 is the base run where no campaigns are carried out. Run 16 spends £20 million on five programs in the South--30 percent to each of cocoa replanting and palm replanting where palm doesn't compete with other perennials (essentially the eastern states), 20 percent to rubber replanting, 10 percent to cocoa new planting, and 10 percent to palm replanting where palm competes with rubber; and £20 million on three programs in the North; 40 percent to each of groundnut and food grains modernization and 20 percent to cotton modernization. Run 11 budgets £40 million in each region for the same programs in the same proportions, and Run 17 doubles the budget again to £80 million, still for the same programs and in the same proportions.

Exports (Figure 9.36) and marketing board revenues (Figure 9.37) are the variables which most directly reflect increased export production resulting from the modernization programs. Interestingly, they indicate diminishing returns for larger campaign efforts. Thus, increasing the modernization budget from £20 million to £40 million increases foreign exchange and marketing board revenues by about £70 million and £14 million (or £3.5 and £.7 per pound of increased budget), respectively. A further doubling of the effort, i.e., another £40 million, would only return an additional £75 million and £17 million in foreign exchange and marketing board revenues (or about £1.9 and £.4 per pound of increased budget), respectively.

Figures 9.38 and 9.39 portray the acreage of each crop in modern production in 1995 resulting from various levels of production campaign budgets. All commodities exhibit the same diminishing returns as foreign exchange and marketing board revenues discussed above.

Figures 9.40 and 9.41 illustrate the diffusion process that takes place as the production campaigns take effect and modern production inputs and techniques are adopted. It is interesting to note that different commodities reach different stages of diffusion by 1995, although each commodity improves its ultimate level of modernization, i.e., increases the number of acres modernized, as the modernization budget is increased. For example, with the £80 million budget, groundnut production (with 40 percent of that budget) starts to level out as it approaches complete modernization by 1995 (Figure 9.40). The replanting rate of palm, on the other hand, is just beginning to increase by 1995 under all budget levels (Figure 9.41).

Conclusions

The major conclusion to be drawn from the above results is that a technological transformation of agricultural export crop production is necessary for sustained growth.[9] Other development policies show only short-run benefits which are eventually eaten up by continued population growth, by activated land constraints and by declining yields of aging perennials. This was true of the tsetse-fly eradication program, where initial gains were later lost to a growing cattle population and to expanding crop acreages. It was also true of the elimination of marketing board and export taxes, where land constraints and declining yields in the South eventually nullify positive results of the higher producer prices. And it was also true of the food grains

9/ *This conclusion is of course dependent on the model's validity and is limited to the policies and programs tested. It is not inconceivable that there may be some other route to sustained growth than the one indicated here.*

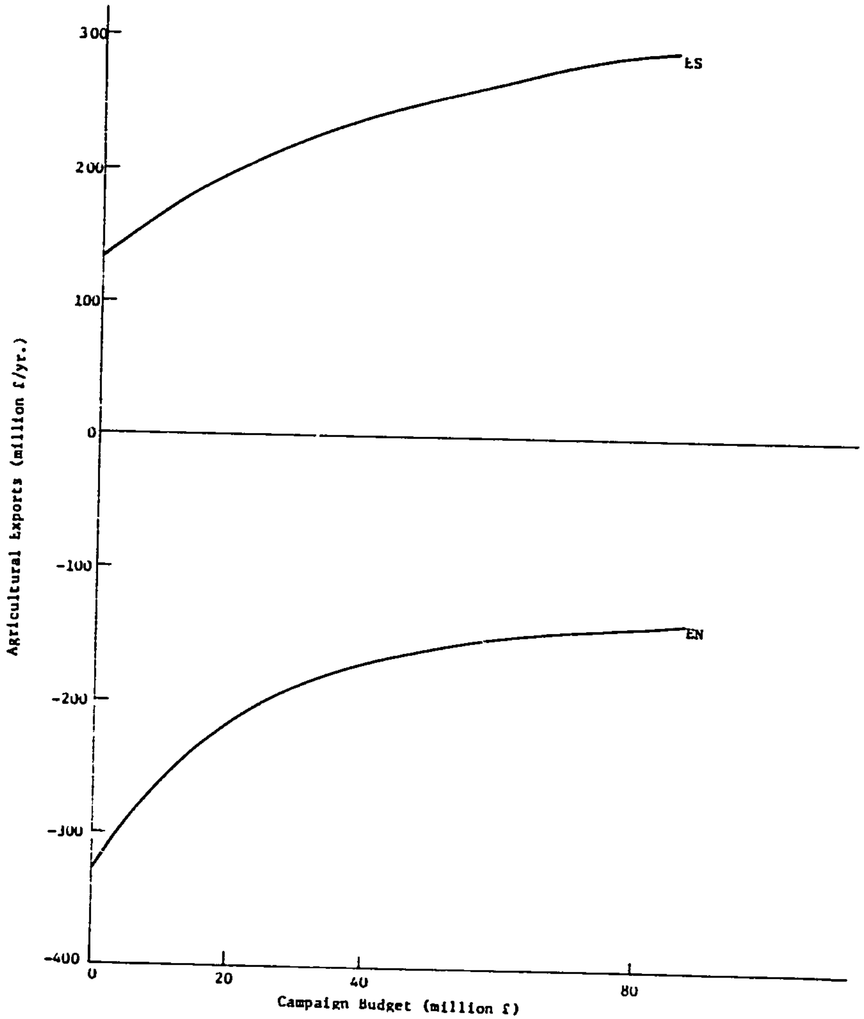

Figure 9.36. Net agricultural exports in 1995 for northern and southern Nigeria under varying production campaign budgets. Net exports from northern Nigeria includes beef and cotton imports.

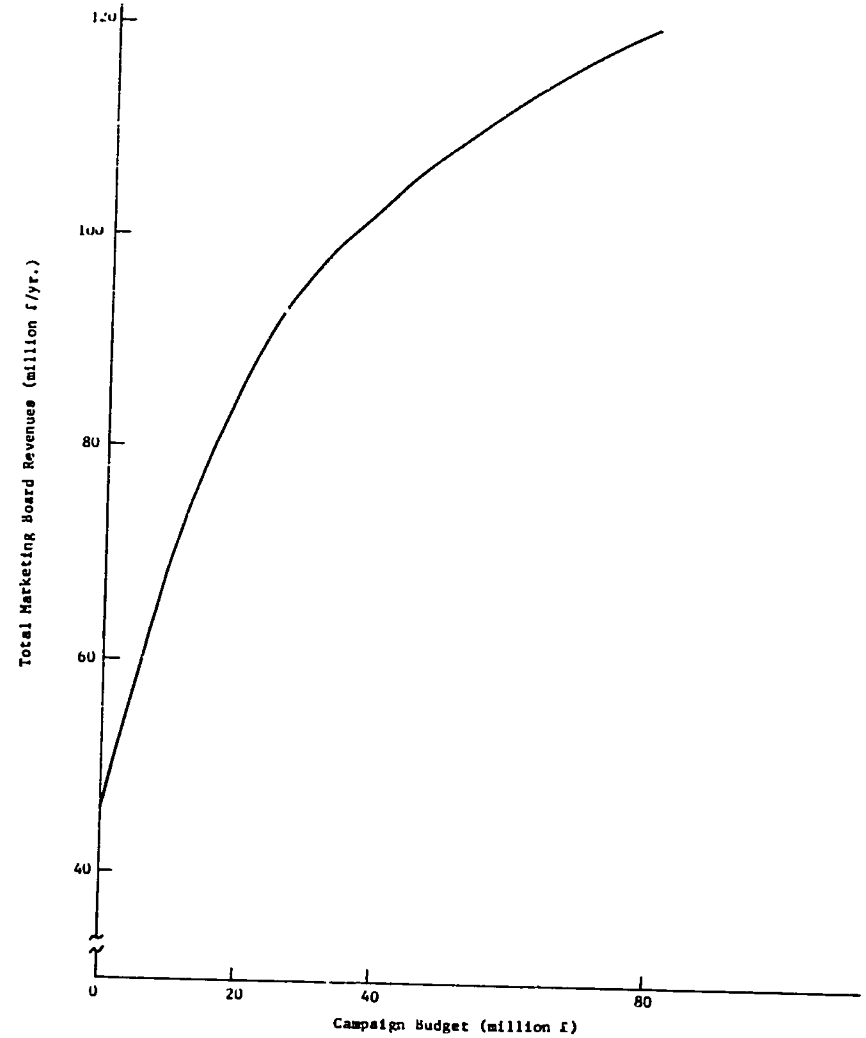

Figure 9.37. Total marketing board net revenues from Nigerian export commodities in 1995 under varying production campaign budgets.

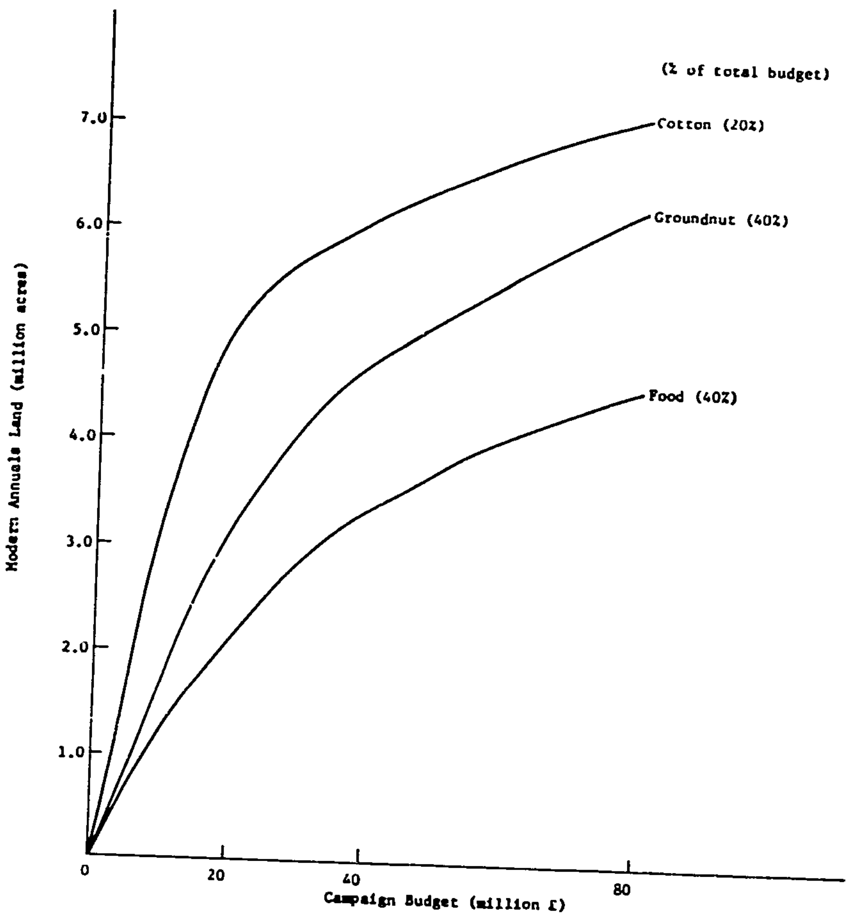

Figure 9.38. Land allocated to the modernized annual crops (cotton, groundnut and food) in northern Nigeria in 1995 under various production campaign budgets.

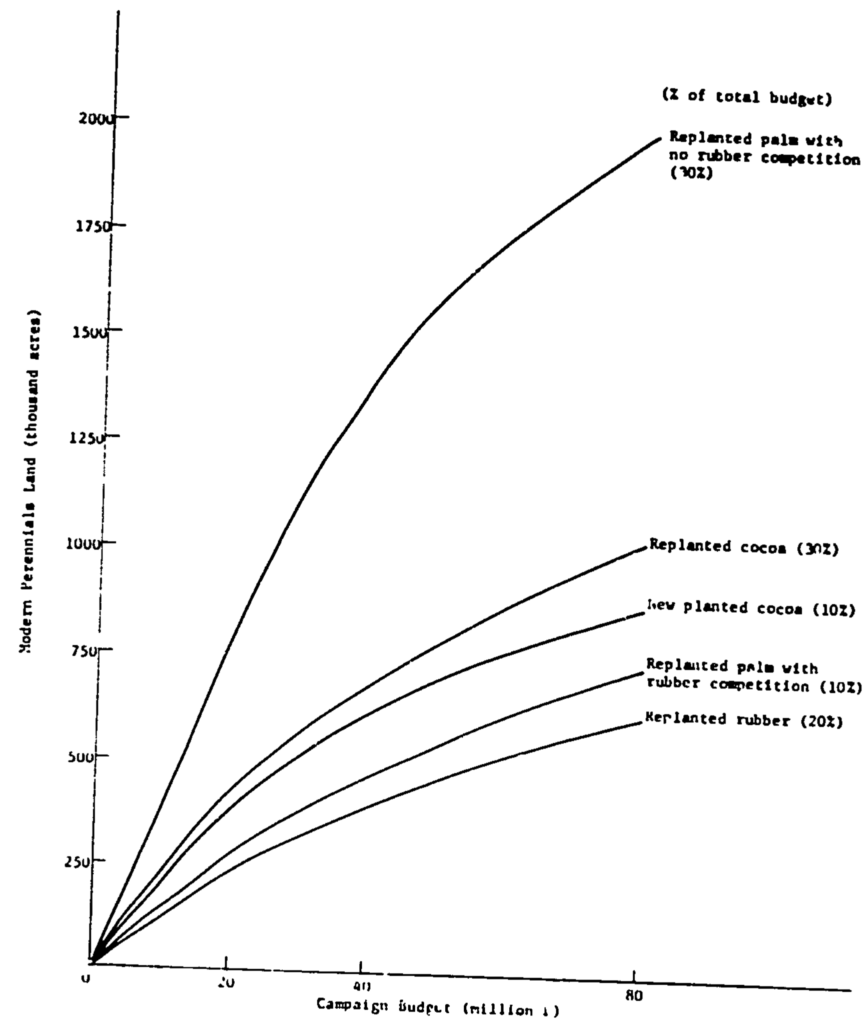

Figure 9.39. Land allocated to the modernized perennial crops in southern Nigeria in 1995 under various production campaign budgets.

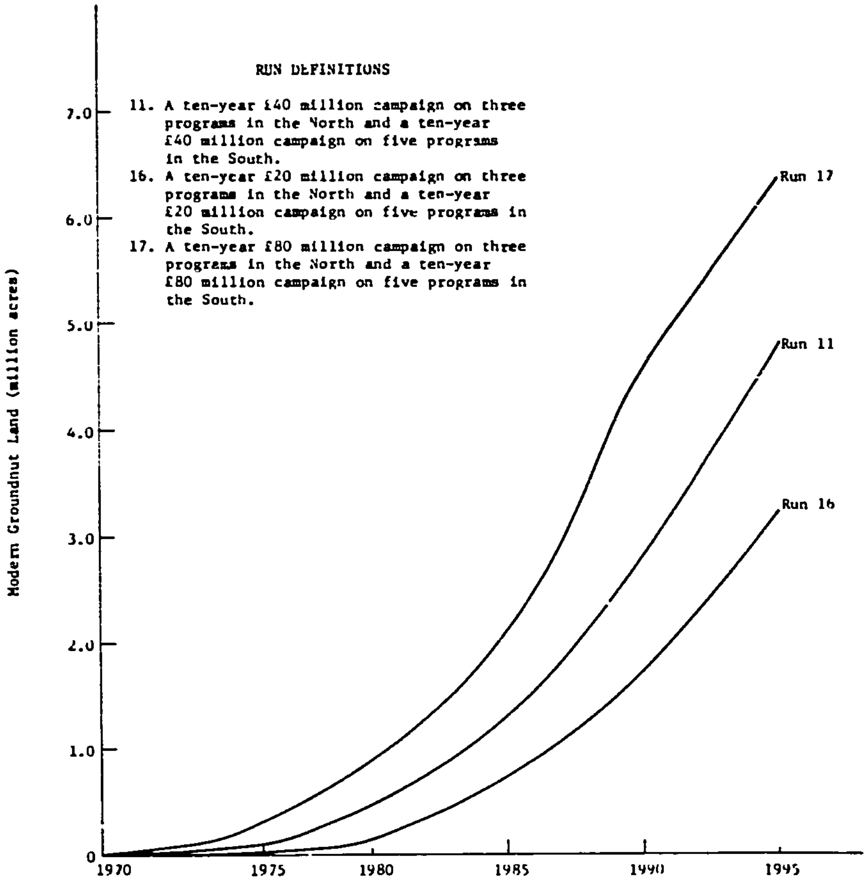

Figure 9.40. Modern groundnut land in northern Nigeria 1970-95, under varying production campaign budgets.

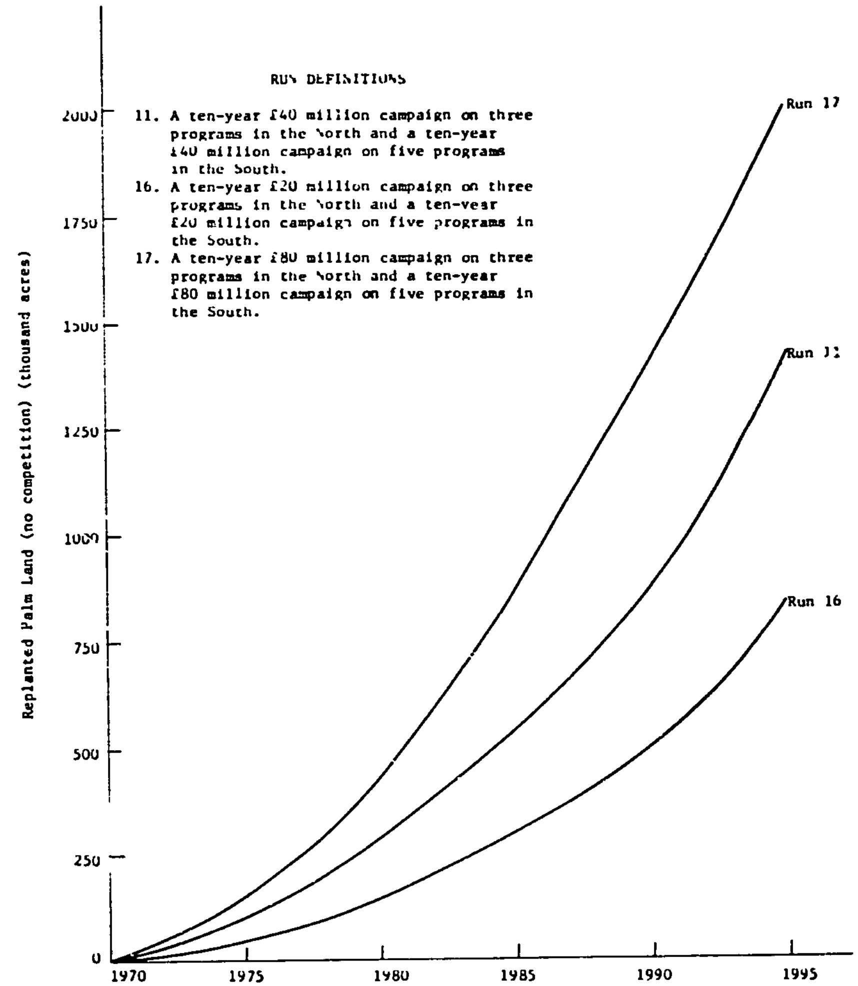

Figure 9.41. Replanted palm land (no perennial competition) in southern Nigeria, 1970-95, under varying production campaign budgets.

modernization programs in the North, where an expanding population eventually reversed the gains made in the increased availability of land and labor for export crop production. Only production campaigns to modernize the production of export crops with the introduction of high-yielding seed varieties and improved cultural practices had beneficial consequences which were maintained in the long run.

Other conclusions can be made from the analysis concerning interregional and intersectoral interactions. North-South shipments of food do play a substantial role in supplying the southern population, and indications are that there exists a potential for regional specialization, wherein the northern Middle Belt area (where roots and tubers, the primary components of southern staple consumption, can be grown) would grow food for a South which would specialize in export perennial crop production.

Interactions between the nonagricultural and agricultural sectors are also strong and indicate that agricultural development can also lead to growth in the nonagricultural sector. For example, rising agricultural incomes increase demand for nonagricultural consumer and investment goods. which means more employment and higher incomes in the nonagricultural sector. This, in turn, means greater nonagricultural demands for agricultural products (food and raw materials) and thus, more agricultural income. And so it goes. This is the multiplier effect referred to in the analysis.

A final observation that can be made from the above policy analysis concerns the production campaign budget levels. Specifically, they show diminishing marginal returns. That is, as the campaigns are intensified (the budgets are incremented), resulting increments in output criteria (such as exports) are less and less.

CHAPTER X
Summary and Conclusions

THIS CHAPTER FIRST SUMMARIZES OUR APPROACH, which we term general system simulation. It then describes the model which we have constructed. This description is followed by a summary of experimental runs with the model. As part of the experimentation with the model, projections of the Nigerian economy's performance were generated, using the model to analyze 21 policy alternatives. As such, the analysis of these policy alternatives illustrates how the model could be used in Nigeria and elsewhere. Shortcomings of our general approach and the specific model developed in this study are then discussed. Following the discussion of shortcomings is a brief section evaluating the general system simulation approach to agricultural sector analysis at the current stage of development. The costs and requirements for developing computerized system simulation models are then considered, along with the prerequisites for successful development and application of the model we have developed.

Our Approach and Its Background

Our general system simulation approach to analyzing problems of agricultural development is viewed as an iterative problem-investigating process that includes problem formulation, mathematical modeling and refinement and testing of the resulting model. These phases of model development necessarily must be done in close consultation with decision makers and, in later application stages, under their partial direction to enhance the usefulness of the agricultural sector planning model being developed. The general system simulation approach provides a vehicle for detailed consideration of those important facets of the physical, biological, social and economic complex which affect development. Thus, a comprehensive evaluation of the primary, secondary and tertiary effects of any program or policy change is possible.

Prior to the initiation of the research reported herein, a conference at Michigan State University indicated that the general system simulation approach was not yet sufficiently well developed to be of practical use in agricultural sector model analyses, such as that being carried out then by the Consortium for the Study of Nigerian Rural Development. That conference indicated that research should be initiated to develop the software necessary to make such applications. The development of this approach was the objective of our research. There was no contractual obligation or immediate objective of making practical applications in any country. Nigeria was simulated because simulating her agricultural economy would permit us to develop the approach, not because there were immediate practical objectives of applying the model in Nigeria. However, it is now evident that (with the further work outlined at the end of this chapter) the model has useful applications in Nigeria and other countries. This report makes the results of our investigations to date part of "the public domain." As such, it is readily available to Nigerian investigators and, for that matter, to investigators from any country who may want to use those components to construct models for use in analyzing the agricultural sector of their own economy.

Some of the pioneering work in applying systems analysis and computer simulation to modeling less-developed economies was done by Edward P. Holland and his associates (Holland, 1966). These and other studies (Manetsch, *et al.*, 1968) attempted to provide policy makers with realistic projections of several physical, economic or biological performance measures from a model based on both the most relevant formal probabilistic estimates of coefficients and less formal estimates for new, previously unconsidered technological, institutional and behavioral alternatives. These estimated results (through time) could be compared by decision makers and investigators in the process of selecting projects, programs and policies. The performance variables are normative in the sense that they measure characteristics of the economy with which "goodness" and "badness" are associated. Interactions between decision makers and researchers may lead to more feedback and improved realism of the model structure, while stimulating the policy maker and investigators to acquire both greater normative knowledge about performance variables and greater positive understanding of the system.

Our general system simulation approach differs somewhat from the probabilistic, equilibrium sets of equations approach in that the system structure is identified without heavy reliance on or preoccupation with, simultaneous linear equations whose coefficients are often estimated from time series data. In our approach, either probabilistic or synthetic estimates of the structure's parameters are developed from various types of available data or knowledgeable people. Physical, institutional and biological processes are often more explicitly considered. The system simulation approach also is well adapted to studying the impact of nonhistorical changes in technology, institutions and people, and is thus more useful in designing and evaluating new projects, programs and policies than approaches tied to historical data series.

The basic building blocks of a simulation model are the physical, biological, economic, social, political and cultural relationships existing within and among the major sectors of the economy. If great complexity and accuracy are desired in the model, a substantial research investment is necessary to design and build a satisfactory simulator incorporating realistic mathematical descriptions of current and potential production, consumption and marketing relationships within the economy. Simulation can incorporate many types of functional relationships--including dynamic interactions, curvilinearities, discontinuities, time lags, probabilities and irreversibilities--into the model to closely reflect current or potential real systems. The chief constraint appears to be the ability of researchers and policy makers to specify accurately the functional relationships among the positive and performance variables of the system.

Our model and its submodels are composed of building blocks interrelated functionally. As such, they can be broken apart into more manageable components because they are recursive in nature--i.e., one function necessarily follows another in time and is dependent upon the output of the previous function--or are seemingly independent (geographic or behavioral) at any one point in time. By specifying the linkages between components (an output from one either being an input to another or a performance variable), the research team members can specify in some detail the functional relationships within each component and proceed to estimate the relevant coefficients. In this way, research efforts can be effectively decentralized within the coordinated, centrally determined format tentatively defined. Later, as model changes and experimentation require, any individual component of the model structure can be more easily isolated and changed than in many other approaches. Prior specification of a single performance criterion to be maximized is not required (although optimization procedures can be employed if a single performance criterion or objective function can be specified). System simulation models can be useful in identifying key information gaps and priorities for further data collection. These insights are gained by "sensitivity analysis," i.e., computer runs testing the impact of changes in model assumptions and coefficient values upon the behavior of key model variables. Such tests can identify parts of the model where errors would cause the greatest inaccuracies in projections or policy comparisons and lead to more efficient data acquisition, parameter re-estimation, and model refinement.

In cases where uncertainty exists as to the estimates for certain model parameters (due to poor or missing information or to inherent randomness in certain parameters), probability distributions can be assigned to such parameters. Models are then run repetitively in a "Monte Carlo" mode with each run incorporating a set of random parameter values drawn from the appropriate probability distributions. Means and standard deviations of performance variables, etc., are then computed from the results of the many individual runs. Thus, Monte Carlo runs permit the policy analyst to evaluate the likely frequency distribution of possible outcomes for different policy options. Further, experience has shown that it is economically feasible to run our models repetitively to acquire these statistics. One simulation run of the entire model costs less than $10 on the CDC-6500 computer at Michigan State University.

Since our general system simulation approach allows the researcher substantial freedom in determining the model objectives, structure and size which best fit the problem situation being examined, it should be less subject to constraints than any one technique or mathematical tool. The option of the simulator to utilize one or a combination of the most appropriate available techniques or to design his own technique where necessary seems likely to result in a tailor-made product more useful to development planners.

Description of the Model

In specifying the model, our concepts of relevant policy-making clientele and their problems determined which sectors and interrelationships needed particular attention within the model and the level of aggregation required. The major sectors and flows incorporated within the simulation model of the Nigerian economy are shown in Figure 10.1. As can be seen from the diagram, our emphasis is on the agricultural sector. Since agriculture contains most of the productive resources in Nigeria (contributing 65 percent of the gross domestic product (GDP) and 66 percent of Nigerian exports in 1962-63) and in most less-developed countries, its role in future growth will be very important.

Many planners in the less-developed countries are interested in evaluating alternative projects, programs and policies affecting regional specialization of production and trade. These typically involve farmer responses to various economic incentives or government assistance projects, etc. Our model has a commodity orientation, emphasizing export crops. To permit considerations of simple questions related to regional specialization and interregional trade, a two region (North and South) model was conceived. However, several ecological zones within each region were also differentiated to permit more detailed consideration of problems encountered within the two regions. Although the model is based on the Nigerian environment, its orientation toward both annual and perennial commodities with distinct ecological zones and regions makes its components adaptable and applicable to a broad range of countries in accordance with the objectives of the AID contract under which the work was done.

The Northern, Southern and nonagricultural submodels are each shown as two interacting parts (in Figure 10.1): (1) demography and (2) production, marketing

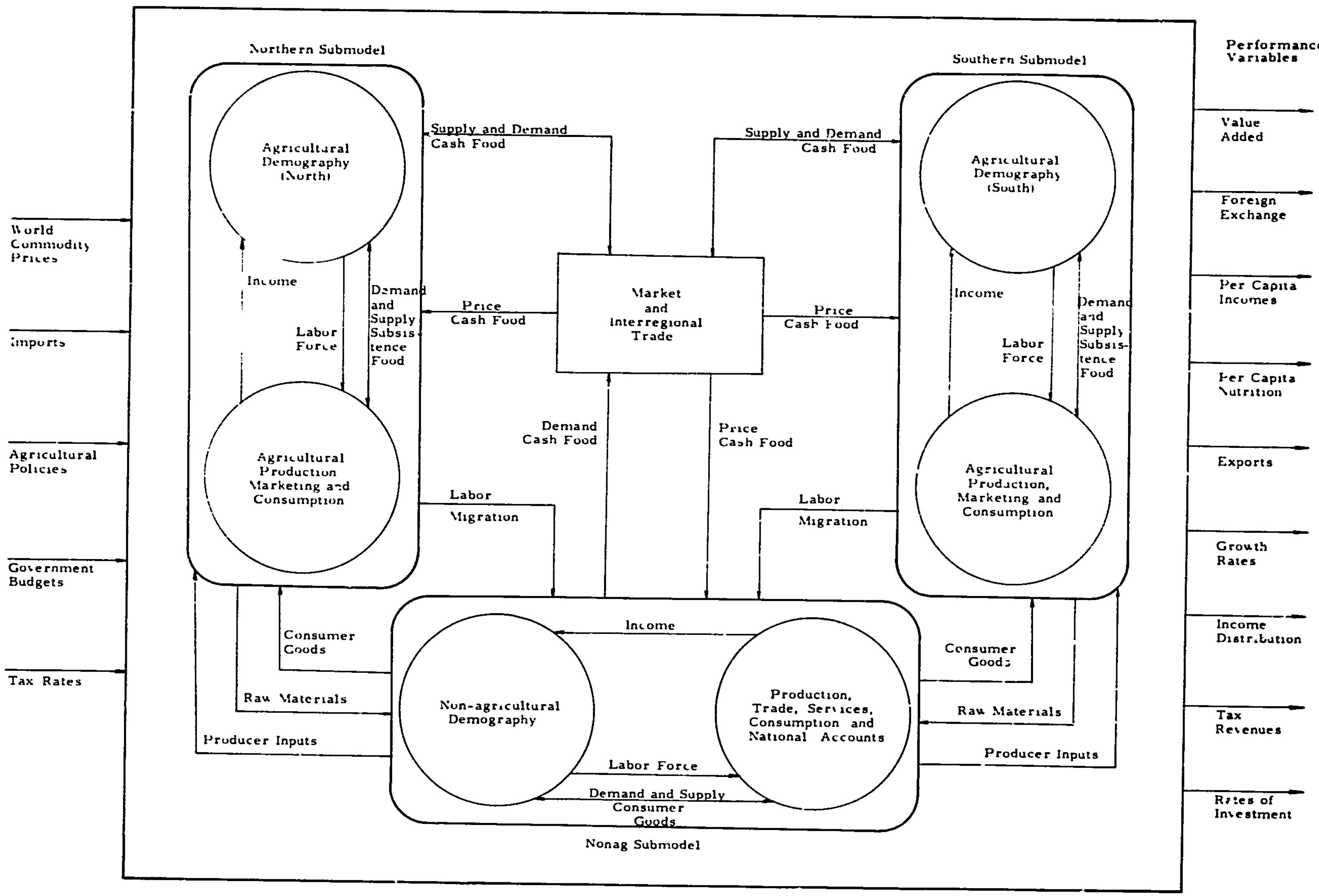

Figure 10.1. National model of interacting submodels.

and consumption. These parts are linked together by income flows, labor supply and the demands and supplies of subsistence foods or, in the case of the nonagricultural submodel, labor supply and flows of consumer goods. The Northern and Southern submodels are linked directly with the nonagricultural submodel through the flow of consumer goods, raw materials for manufacturing and agricultural producer's inputs supplied by the nonagricultural submodel. Labor migration can take place between the agricultural and nonagricultural submodels. The major interaction among the three submodels takes place through interregional trade in food which is simulated by a market and interregional trade component.

Submodel of Northern Nigeria

The Northern model consists of six interacting components. (For further details see Figure 4.1 and Chapter IV.) The cattle production component simulates the meat and milk production process in traditional and modern herd management situations, using inputs of total digestible nutrients (TDN) from the production of various forage and grain crops. The main interaction between the cattle and annual crop components in the Northern model is the land allocation component where the acreage in various crops partially determines the quantities of total digestible nutrients available in the cattle component.

The agricultural production and marketing component simulates the production and marketing activities for groundnuts, cotton and food. Land use is determined by the land allocation component, prices for food by the market component and yields by the modernization component. In turn, the production and marketing component computes average returns to land and labor, which affect farmer's land allocation decisions. The value added at each stage of production and distribution is also computed in the production and marketing component and utilized in calculating the national accounts in the nonagricultural component.

In addition, the market component of the total model simulates the price mechanism of the cash food market in each of the regional models. This component traces the shifts in the demand for food and utilizes the calculated food supply to determine the price of food.

The consumption and budget component computes a number of agricultural sector variables needed by the nonagricultural model. There are expenditures on chemical inputs, capital goods and consumer goods derived from the calculated income and population levels in the North. The component also computes disposable incomes from production and marketing, for use in the nonagricultural model, and per capita income by region in the North.

Submodel of Southern Nigeria

The Southern model is composed of five interacting components. (For further detail, see Figure 5.1 and Chapter V.) The agricultural production, marketing and processing component computes the production from acreages of traditional cocoa, modern cocoa, traditional palm, modern palm, traditional rubber, modern rubber, food and tobacco by simulating commodity yields and food subsistence levels of the agricultural population. Marketing and processing are modeled, using accounting equations based upon fixed relationships related to the product. Input demands--labor, capital, chemical and biological materials--are calculated for the functions of production, processing and marketing. These variables provide the main interaction with the nonagricultural component of the national model.

The land allocation and modernization component of the Southern model simulates farmers' allocation of land to the traditional or modern production of cocoa, palm, rubber, tobacco and food based upon economic, physical and cultural factors.

The third component of the Southern model generates world, market, processor and producer prices for the five commodities considered in the previous two components. Two additional components provide further interaction with other components of the national model. The allocation of the agricultural modernization budget (from the national budget) is made by the modernization program and policies component. The accounting component of the Southern model computes values for the performance variables for the Southern model as a whole, and provides inputs to the national account section of the nonagricultural model.

Submodel of the Nonagricultural Sector

The nonagricultural model has a dual purpose within the national model. In a broad, rudimentary way it models the nonagricultural components of the economy, enabling key interactions between agriculture and nonagriculture to be studied. (For further details see Figure 7.1 and Chapter VII.) The nonagricultural model simulates the demand for food by the nonagricultural population and manufacturing demand for agricultural raw materials. Likewise the model simulates the supply of agricultural inputs, such as chemical materials and fertilizer, and the supply of consumer goods and services to the agricultural population.

The nonagricultural model also summarizes the accounting variables of both the agricultural models and the nonagricultural sector, and constructs national accounts and balance of trade tables. These include measures of gross national (domestic) product by branch of activity and category of expenditure, government revenues, and import-export balances.

Summary of Simulation Experiments

In this section we will summarize conclusions reached relating to the Nigerian agricultural economy. While the objectives of the project did not specifically include applications to policy making in Nigeria, the process of building and testing the many components and models described herein has led to a number of insights into problems and potentials of the agricultural economy of that country.

Simulation Experiments With the Northern Model

The Northern model dealt with the production of cattle and annual crops in northern Nigeria. A number of tests were carried out with the cattle component of the model (see Tables 4.1 and 4.2 of Chapter IV). Also a number of developmental strategies were explored for improving the efficiency of the traditional (Fulani) production system. These included management policies to change the herd composition by reducing the number of males and reduction of total herd population with a consequent increase in per capita animal nutrition. Neither of these yielded highly significant improvements in output and efficiency, though the former scheme proved to be comparatively more effective.

Another simulation experiment explored the impact of expanding available nutrition by clearing the tsetse fly from grassland in the Middle Belt. At the assumed costs of clearing and keeping clear tsetse-infested land (£3/acre to clear and keep clear for 20 years), this did not appear to be advantageous (see Table 4.2). The dominant conclusion reached on the basis of policy runs with the traditional cattle production system is (1) that there seems to be very little that can be done to produce significant changes in efficiency and output of the traditional system on a long-term basis, and that (2) a totally different, non-nomadic production system may be needed. Further work in the development of feasible alternative production systems, perhaps including mixed farming enterprises, would seem to be of high priority, particularly in light of the substantial foreign exchange deficits generated by cattle imports required to meet the rising domestic demand for meat. (See Table 4.2 and related discussion.)

Model results also confirm the conclusions reached by others that in terms of value of production, the milk output of the northern cattle herd grosses more income than the output of meat. It is important to underscore this fact, since it undoubtedly affects the nature of development programs and policies which should be considered for the industry and the likely response of Fulani herdsman to these policies and programs.

Turning to the remainder of the Northern region model and the regional agricultural economy, experiments with the model indicated that in its present form the model is capable of coarsely tracking aspects of the economy over the period 1953-65 (food prices, groundnut production and cotton production). Preliminary policy runs made with the model indicated that if certain preconditions are met, substantial increases in output, income, foreign exchange earnings, etc., are possible under programs and policies favorable to agricultural development. Specifically, the following were found to be of particular interest:

1. Marketing board price policies designed to increase producer prices for groundnuts and cotton by reducing marketing board revenue surpluses;

2. Production campaigns to promote improved production practices for groundnuts, cotton, and food crops that compete with these export crops for land and labor.

The model indicated that allocating public resources to both improved food and cash crops (groundnuts and cotton) had greater impact than allocating the same resources to groundnuts and cotton alone. (See Table 4.4 and related discussion.) This is because increased yields of foods allowed farmers to release land and labor for cultivation of more cash crops. It is important to note that such production improvements are not feasible in the model (are not widely adopted by farmers) unless the production campaigns include some method of reducing the labor requirements of the improved practices. Further, the experiments with the model indicated that (1) and (2) above are much more effective if carried out concurrently rather than separately. (See Table 4.4 and related discussion.)

Some model runs assessed the impact of a production campaign designed to introduce and promote improved production practices into the cultivation of root food crops not in competition with groundnuts and cotton. Such a campaign resulted in a net decrease in farm income due to reduced food prices. On the positive side, however, the urban population was fed at a significantly higher level of nutrition under this program.

Numerous additional policy experiments are possible with the model. These would logically follow a careful review and refinement of the model (its structural assumptions and supporting data). Certain areas of the model require particular scrutiny. For example, is it reasonable for nearly all cash food production to be allocated to the region producing root foods (yams and cassava in Region 4)? Is the assumption realistic that food grains cannot compete with groundnuts and cotton and do not normally appear in the cash food market? Could the current disparity in regional per capita incomes produced in some simulated policy runs (in Regions 1, 2 and 3 (groundnuts. cotton and competing food grains) and Region 4 (root food crops)) really exist? Would it be useful to link the cattle production component of the Northern model with parts of the marketing model developed by Kellogg (Kellogg, 1970) in order to improve the simulation of beef production, consumption and pricing? One can conclude that the Northern region model is useful in its present form but requires further evaluation and refinement if greater accuracy is desired.

Simulation Experiments with the Southern Model

While additional work remains to be done before the annuals/perennials model of southern Nigeria is ready to be operationalized on a regular basis, conclusions can be made regarding the model's actual and potential applicability and some development implications can be drawn from current model results.

The Southern model was adjusted to track four actual time series from 1953 to 1965: the market price of food and exports of cocoa, palm oil and rubber. While tracking four time series is not enough to actually validate the model, the resulting fit was sufficiently good to provide some confidence about the reasonableness of the model.

Sensitivity tests on the Southern model indicate that substantial impacts on prices, incomes and consumption patterns can result from small changes in various model parameters, such as initial acreages, yields, elasticities and marketing losses which are related to the supply and demand behavior for food and palm products. The sensitivity of the model to these parameter changes is due to an inelastic supply and demand structure.

Policy experiments were conducted on the Southern model to examine the consequences of three of the production campaigns defined in Table 5.2. The three campaigns are run independently and in various combinations. In addition, marketing board price policies were tested in combination with the production campaigns. The three campaigns tested new planting of modern cocoa, modern rubber replanting and improvement of traditional palm (in the Palm Sector) and were chosen as illustrative examples because they affect different commodities, different ecological zones in the South and different approaches to perennial modernization.

The simulation results indicate (see Chapter V) that marketing board policies more favorable to the producers would result in moderate increases in agricultural incomes and export earnings. For example, by 1963 foreign exchange earnings increased more than 2 percent and disposable income in the Cocoa Sector increased about 4 percent over the base run (involving no production campaigns and normal marketing board surpluses). These increases were more substantial when production campaigns accompanied favorable marketing board policies. For example, when the three combined campaigns were run in conjunction with favorable marketing board policies, Cocoa Sector income increased 22 percent (by the end of the run) over what it was when the same campaigns were run under normal marketing board policies.

The production campaign experiments suggest that the palm and cocoa programs defined in Chapter V may produce large gains for the South. Improving traditional palm postpones the time when the domestic demand for palm oil exceeds supply and exports fall to zero. In the last 13 years for which data were available (1953-65), Nigerian exports of palm oil fell about 33 percent (Table 5.3). The model simulates a continuing decline until exports cease around 1983. Under the palm improvement program, this point of excess domestic demand is delayed about four years.

Expanding cocoa capacity with modern biological varieties and methods significantly improves agricultural incomes and exports, particularly when accompanied by increased marketing board producer prices. In fact, Table 5.7 suggests this policy for the South is advantageous in terms of southern agricultural disposable income.

Bear in mind that this series of policy runs is only a limited illustration of the kinds of experiments which may be conducted with the model. The model is capable of investigating many more combinations of production campaigns, marketing board policies and taxes, and other programs. After some additional refinements are made in the model (especially in the palm region parameters, see Chapter V for detailed concerns), simulating various budgets, policy mixes and scheduling of the introduction of new technologies and management combined with alternative marketing board policies for the perennial crops appears to be a very fruitful area of further policy research.

Two types of model refinements are required before the Southern regional model will be fully ready for application: data improvement and further development of the structural relationships of the model. Priority areas for data collection, e.g., crop acreages and marketing losses, were identified by the sensitivity runs discussed in Chapter V. Although sharper data estimates would be useful in making the model's predictions more precise, increased precision may not alter the relative consequences of various development policies. Thus, the current level of accuracy may be sufficient as long as the <u>relative</u> consequences of alternative policies are more relevant for the policy maker than the <u>absolute</u> levels of output criteria.

On the other hand, structural relationships in the model may have a significant impact on the relative policy consequences which the model may project. Several structural relationships and assumptions need to be examined more closely and either confirmed or modified. Some notable examples are the palm oil demand and supply functions (discussed in Chapter V and modified in the revised model), the omission of possibly feasible and significant land use alternatives from the model (Table 5.1), and the assumption that labor is not a constraint in the South. By considering modern palm varieties rather than improving traditional palm, the payoff to palm modernization may be substantially improved over what our current simulation experiments show. Further, the explicit consideration of likely groundnut oil- palm oil substitutability and food crop- palm oil substitutability in domestic consumption may cause the decline in palm oil exports to be much less severe than the current model runs project.

In conclusion, the sensitivity tests and policy runs conducted with the Southern annuals/perennials model have been useful in the tuning and validating of the model, and illustrating the types of questions the model can address. In addition, these tests have pointed out areas of the model which need further development and refinement before the model can be fully operationalized as a regular contributor to the development planning process. Even after such implementation, further validation and updating would be necessary, continuing activities accompanying the use of the model.

The Utility of the Nonagricultural and National Accounts Model

Unlike the Northern and Southern agricultural models, the nonagricultural and national accounts model was not designed for policy experimentation, but rather to interact with the agricultural simulation models in agricultural policy evaluations. In this respect the results of the model emphasized the importance of agricultural-nonagricultural interactions to the agricultural sector. An increase in agricultural incomes at a given point in time produces a multiplier effect on both sectors of the economy through the interaction and feedback effects of the nonagricultural economy. Indeed, as long as food prices remain unchanged, the effect will usually be greatest in the nonagricultural economy. This important result can be explained by the higher income elasticity of demand for nonagricultural goods compared with food.

The nonagricultural and national accounts model is considerably more aggregated than the agricultural simulation models. It also treats many coefficients (e.g., input-output and capital-output ratios) and variables (e.g., oil exports) as exogenous in the model. This is a limitation to using the model for predictions more than a few years into the future. As we indicated in Chapter VII there are several directions in which the model could be expanded to improve its predictive ability in application to a specific country. However, in its present form the model does have general applicability as there is very little in its structure that is unique to the Nigerian economy.

Finally, the nonagricultural and national accounts model in its present form emphasizes the flows of goods and services between the agricultural and nonagricultural economies. It treats inadequately the flows of labor and capital between the two sectors of the economy. Although much of our economic theory in this area is inadequately developed, there is no doubt that migration of labor and the flow of capital between the two sectors are largely determined by internal economic adjustments, not exogenously, as assumed in the model.

Policy Simulation Experiments with the Nigerian Model

Several agricultural development policies were tentatively evaluated and compared to illustrate the use of the Nigerian model. While the comparisons should be interpreted cautiously, due to the preliminary nature of the model relationships and the assumption that the economy evolved in a normal fashion after 1965, they do provide some insight into the structure of the model, some potential model applications, some model deficiencies and the interactions of various policy combinations. Policy runs were made in two sets. The first used the model described in Chapters IV-VII, while the second set of runs employed a later version of that model which incorporated modifications and corrections suggested by earlier testing and experimentation.

Five agricultural policies which were arbitrarily selected for evaluation with the model presented in Chapters IV-VII include:

1. Essentially a status quo agricultural policy situation, involving current marketing board policies and no major crop modernization programs;
2. Changing the marketing board policy for export crops by increasing producer prices for groundnuts, cotton, cocoa, palm oil and palm kernels by 25 to 30 percent, making the marketing board a "nonprofit" operation;

3. Introducing a combination of export crop modernization programs involving government programs to modernize groundnut and cotton production in the North, to apply modern production methods and inputs to traditional palm trees in the South, to replant traditional rubber with modern rubber in the South and to encourage new plantings of modern cocoa on bush land in the South. These programs were funded for a 10-year period from 1965-75, with 12.5 million pounds budgeted per year during the period of maximum expenditure from 1967-73;

4. A combination of crop modernization programs, (those specified in (3)) and improved marketing board prices (as specified in (2));

5. Introducing a food crop modernization program in the Middle Belt of Nigeria, with a maximum budget of 5 million pounds per year during the maximum expenditure period of 1967-73.

The likely impact of each agricultural policy was projected over a 28-year period. The simulation results point out some interesting features likely to be associated with some of the policies which were tentatively studied. For example, increased marketing board producer prices (Policy 2 above) on export crops stimulated a moderate growth in value added in agriculture and GDP's, with substantial increases in agricultural workers' incomes in the Northern annual crop region being noted, particularly during the first 8 years of the program. Southern agricultural worker incomes exhibited a fairly gradual, longer lasting rate of increase due to the longer gestation period required for change to exert an impact in the perennial export crops in the South.

The export crop modernization program had very little effect on GDP during the first 12 years of the simulation run compared to the status quo run, but exhibited a substantially increased rate of growth compared to current agricultural policies in the years following that (after the lag between efforts to stimulate adoption of these new practices and technologies and the subsequent output changes). In this program, the agricultural incomes to workers in the North increased at about the same rate and timing as the incomes of agricultural workers in the South, with an increasing rate especially noted 15 to 20 years after initiation of the program in both areas. This may suggest that the modernization policies defined were comparatively more advantageous for the export crops in the South, since agricultural worker incomes in the North did not begin their significant increases until the South became more dependent on the North for food crop production 15 to 20 years after the initiation of the export crop programs.

Combining improved export crop production technology and management with improved export prices for producers led to the greatest growth in agricultural exports, both gross and per capita returns to agricultural resources and GDP. The complementarity of these programs instigated a stronger and more uniform rate of growth than did either of these policies independently. It appears that the marketing board policies stimulated the initial boost in export crop production and agricultural incomes, while the modern technology stimulated a sharper rate of change after the first decade when the growth attributed to marketing board policy changes tapered off. While the latter two policies stimulated the greatest growth in exports and GDP's as well as agricultural incomes, they also stimulated the greatest increase in food prices, as a result of their impact on the effective demand for food in the cash markets and the incentives provided to farmers to switch to higher income export crops. Consequently, food prices rose significantly over the 28-year period, but the multiplier effect of the increased agricultural incomes and expenditures on nonagricultural products had a significant impact on nonagricultural incomes, causing their caloric consumption rate to be greater than it would have been if no changes in agricultural policy had been implemented.

The policy of modernizing food crops in the Middle Belt of Nigeria caused a slight decline in GDP and value added in agriculture compared to the status quo policy; however, the caloric consumption rate in nonagricultural sectors of the North and South exhibited substantial increases compared to all other policies which were explored. Thus, the net impact of a food modernization program within presently available technology in the Middle Belt would probably be strongly positive for non-agricultural workers, positive for the agricultural workers in the Middle Belt of the North, neutral for Northern agriculture as a whole, and very likely negative for agricultural workers in the South when comparing the resulting real income of each group. If substantial advances are made by feed and food grain and cash crop plant breeders, these simulated projections would be modified substantially.

To further explore the effects of various policy combinations and budget levels, the model was revised, and some new policies were defined after some additional limited interaction with Nigerian policy makers and planners. A series of 16 additional policy runs explored a tsetse fly eradication program, cutting off and phasing out marketing board and export taxes, some regional production campaigns for export crops and food crops (separately and in combination) and the introduction of new processing technology. In addition, the relative consequences of varying the levels of production campaigns budgets were investigated. Policies were run individually and in increasingly complex combinations on the regional and national levels to examine interactive and feedback effects among them.

The tsetse fly eradication program causes a dramatic increase in the amount of fly-free grazing land available to cattle, and a corresponding increase in slaughter rate and incomes from animal sales and milk during the first 15 years of the program. After the herd size reaches and again exceeds the carrying capacity of the range land available, the range condition and incomes decline again at approximately the same rate as before the fly eradication program. This suggests that the program produces only short-run benefits, and the time so gained should be used to develop and implement programs with more permanent benefits.

A gradual phasing-out of marketing board and export taxes for export crops causes a slightly slower growth rate in exports and agricultural incomes than the abrupt elimination of these taxes; however, the long-run results of the two programs appear quite similar after the first decade.

Production campaigns to modernize export crops (annuals) and food crops in the North and export crops (perennials) in the South appear quite complementary, as increased food yields free substantial acreage for cash crops while shifting the cash crop planting time earlier, resulting in even higher cash crop yields than would otherwise be possible.

A program of introducing new processing technology into the palm oil and rubber industries tentatively indicated that the Stork hydraulic palm presses are technically more efficient than current techniques, but are economically unprofitable. Centralized crumb rubber factories, on the other hand, proved to be more efficient and profitable than traditional means at the village level.

Finally, the marginal impact of varying production campaign budget levels was found to decrease as budget levels were increased; the search for the right combinations of budgets and policies can be facilitated by this type of experimental policy simulation.

The illustrative policy runs also demonstrate the capability of a complex, dynamic agricultural sector model to exhibit differing policy effects at sublevels of the economy. The differing responsiveness over time of perennial versus annual crop policies was particularly striking in policy campaigns. Regional impacts were strikingly different in the food crop modernization policies which were simulated. The multiplier effects of these policies (or effect on nonagricultural growth) varied directly with the real output and income of agriculture. Also the differential impact of some policies on various groups within the population was particularly noteworthy when evaluating the food crop modernization policies, with some groups substantially better off, some worse off. The complementarity of some policies, e.g., higher prices combined with introduction of new technology through food and export crop campaigns, was aptly demonstrated in one case; this type of complementarity can be found by experimentation with this type of model.

These runs also raise some questions about model application in its current form. Did the secession cause changes in the economic structure which will invalidate even the relative results of some policies? Would changes in the model and information on which it is based (more or less optimistic world price projections, faster reactions to profitable crop alternatives, etc.) change these comparative results?

The major conclusion to be drawn from the above results is that a technological transformation of agricultural export crop production is necessary for sustained growth.1/ Other development policies show only short-run benefits, which are eventually eaten up by continued population growth, by activated land constraints and by declining yields of aging perennials. This was true of the tsetse fly eradication program, where initial gains were later lost to a growing cattle population and to expanding crop acreages. It was also true of the elimination of marketing board and export taxes, where land constraints and declining yields in the South eventually nullify positive results of the higher producer prices. And it was also true of the food grains modernization programs in the North, where an expanding population eventually reversed the gains made in the increased availability of land and labor for export crop production. Only production campaigns to modernize the production of export crops with the introduction of high-yielding seed varieties and improved cultural practices had beneficial consequences which were maintained in the long run.

Some Conclusions on Judging Acceptability of Simulation Models and the Role of Decision Makers

One of the most difficult aspects of model building is that of validation. This problem is present regardless of the complexity of the model or of its nature. In attempting to be useful to decision makers trying to prescribe which course of action is "right", questions of verification arise with respect to both the normative and non-normative (or positive) contents of the model as well as the prescriptions themselves. While certain philosophies preclude the possibility of verifying the normative content of a model, we have elected not to follow them in putting normative questions beyond appeals to logic and experience. Hence, the following

1/ *This conclusion is of course dependent on the model's validity and is limited to the policies and programs tested. It is not inconceivable that there may be some other route to sustained growth than the one indicated here.*

discussion of verification will fall under three headings: the positive or non-normative, the normative and the prescriptive.

By positive or non-normative content, we have in mind the meaning of concepts which describe conditions, situations and things independently of their goodness and badness. Our concepts on the non-normative or positive side remain acceptable so long as they: (1) have not been proven logically inconsistent; (2) are empirically consistent with our experiences, with recorded Nigerian history, with specific technological, geographic and institutional information and with theory, both economic and noneconomic; (3) can be transmitted from one person to another in a meaningful way, and (4) "work" when we use them to solve a problem. These are the tests which we have used in verifying the non-normative or positive components of our model. (See the section on model refinement and theory in Chapter III.) Positive elements of the model which have not met these tests to date have been eliminated and replaced. The elements which are retained are merely those which have not failed these tests and, as such, must not be regarded as immutable knowledge but as fallible in the best scientific tradition.

We have, in effect, used the same criteria in determining the acceptability of the normative content of our models. The output or performance variables which we have used are, of course, normative. As such, they describe characteristics of conditions, situations and things in terms of good and bad (as contrasted to non-normative or positive concepts which do not deal with goodness and badness). We have not tried to define the meaning of the words good and bad; instead, we have taken it to be a primitive term like the words, mass, time and volume, on the non-normative side (which we either do or do not know the meaning of and which are basically undefinable). In testing the acceptability of normative concepts and components of our models, we have applied the tests of logical consistency and have drawn upon the experience of mankind (Nigerians in particular) with the goodness and badness of such things, conditions and situations as high versus low per capita incomes, adequate versus inadequate nutrition, the presence or lack of presence of personal freedom, etc. We feel that we have attained a certain degree of interpersonal transmissability of these concepts and have rejected certain criteria as unworkable in terms of solving Nigerian problems.

Prescriptive concepts as to what is right or wrong depend upon the decision-making rule employed. In economics, the decision-making rules commonly employed assume a common denominator among the goods and bads such that a single objective function can be defined for maximization. Our decision-making rules ordinarily assume the prior establishment of the mathematical conditions for locating that maximum difference. If damages are imposed on some people at the expense of others, our ordinary economic principles require that the objective function have interpersonal validity before we can specify which action is the best or right among the many which would impose bads on some people in order to confer goods upon others. By contrast, and generally speaking, in our simulation models we have not assumed a specific decision-making rule for prescribing solutions; nor have we assumed the existence of a common denominator among the goods and the bads involved. We have used certain measures of good and bad as multiple criteria variables but have not attempted to reduce them to a single objective function. Furthermore, we have not assumed the existence of any known order in which to execute sequences of actions in developing a program or sequences of programs in executing a policy. Instead, we have been flexible and have left these things unspecified. As a result, our models tend to trace out the paths through time of certain performance variables without arriving at prescriptions as to what projects, programs and policies are right to execute. In this sense, the prescriptive components of our models are very incomplete. We prefer to leave them that way.

We could make untested, uninvestigated and, hence, unrealistic assumptions in order to establish a single objective function, the necessary second order conditions for maximizing that function and the decision rule to use. Rather than proceeding in such an unrealistic way, we chose instead to build models which would predict the time paths of various criteria variables for display at some later date to relevant decision-making agencies and persons. At such time, we feel that interaction between decision makers and investigators will result in considerable improvement of the model. In making these improvements, the normative and non-normative components will be modified or extended, thereby (1) minimizing the need for arbitrary assumptions and unnecessary rigidities and (2) increasing model realism, applicability and usefulness. Hopefully, after substantial interactions between decision-makers and investigators, our models will be sufficiently developed to permit the insertion of realistic decision-making rules and the eventual direct use of the model by decision-making agencies and individuals in selecting among alternative policies, programs and projects.

Shortcomings of the Approach and the Model

Our generalized system simulation approach is subject to a number of general shortcomings. The models produced by this approach are not easily explained. Unlike more specialized, recursive, linear programming models and sets of simultaneous equations, the general models of the type we are dealing with cannot be written out in simple matrix notation; instead, large numbers of recursively linked differential equations have to be described equation-by-equation and component-by-component. While general diagrams can be drawn illustrating how the equations and components are linked together, they are neither mathematically elegant nor satisfying to the person who would like a simple total comprehension of the model from which he can derive, deductively, details concerning the model itself.

Another shortcoming grows out of the computational efficiency of linked differential equations. This advantageous characteristic leads to a shortcoming of the approach. Because computational efficiency is greatly reduced when components involving iterative solutions are introduced, there is a temptation to omit components containing such elements so as to maintain computational efficiency even when they "should be" used.

In addition to the general shortcomings of the simulation approach discussed above, there are substantive shortcomings of our model which should be made clear. In general, our components do not adequately deal with irrigation, mechanization and income distribution. In addition, we are dissatisfied with our components for modeling off-farm migration, investment in durables, disinvestment in durables, the generation of specialized farm produced capital and aggregation of individual responses of firms and households into supply and demand responses. These dissatisfactions grow out of underlying deficiencies in economic theory. Generally speaking, economic theory does not adequately handle user and opportunity costs in relation to acquisition costs and disposal values of durables. User cost is related to the rate at which services are extracted from durables. As such they are bounded on the upper side by acquisition costs and on the lower side by salvage values. When more than one use of the services of a durable exists, user costs must also be equated with opportunity costs. The difficulties with our components stem basically from inadequacies in general economic theory for dealing with user costs, opportunity costs, acquisition prices, and salvage values in connection with decisions to invest or disinvest in fixed durables. The generation of farm-produced capital from fixed resources is inadequately handled in our components, again due to deficiencies in economic theory. Similarly, off-farm migration (which can be conceived of as the disinvestment of the agricultural sector in a fixed durable, namely, laborers) is inadequately modeled in our components.

Our models are also deficient with respect to components for dealing with the origin of changes in technology, institutions and the human agent. While it is true that we have modeled some aspects of agricultural research and agricultural education, our models are oversimplified and naive with respect to the complex real-world processes of creating technological advance and human change. Similarly, our components are inadequate for modeling the political processes of changing institutions, though this deficiency would be partially remedied in applications involving interactions between simulators and decision makers. In a very real sense, the deficiencies in our models with respect to technological, institutional and human change result from inadequacies in theories of sociology, political science, psychology and, in the case of technological change, theories explaining technological advance. Whenever progress is made along these lines in the corresponding parent disciplines, opportunities will arise for greatly improving the components of our models.

Another set of substantive shortcomings of our model involves the inadequacy of those components dealing with the behavior of farmers, consumers and others. Generally speaking, our components incorporate lags and oversimplified adjustment processes. As improved theory concerning the dynamic behavior of entrepreneurs and housewives becomes available, it will be possible to improve these components. However, unlike the case for technical, institutional and human change, we do not feel that we have exploited available managerial theory as fully as sociological and psychological theory in designing the components dealing with consumer and managerial behavior.

Our models currently do not include public decision-making rules for prescribing which actions are right or wrong, though several behavioral components are based on the assumption that producers and consumers use decision rules involving various forms of maximization. Generally speaking, our models have not yet been used to prescribe, in and of themselves, which public project, program or policy should be executed. Our models are designed to help administrators reach such decisions but cannot be regarded as complete in this respect. As we see it, their completion, in this respect, depends upon intensive interaction between investigators and decision makers, as will be discussed below.

Another deficiency in our model results from severe shocks to an economy which the model does not handle. This also affected our data acquisition activities and interaction with Nigerian decision makers. The secessionist difficulties and our contractual obligations to develop, but not apply, our models have limited our interaction with high-level Nigerian decision makers, though a large number of Nigerian scholars and students have provided helpful criticisms, suggestions and information. With the Nigerian crisis at its peak during the period of time in which the research reported herein was completed, it would have been both inappropriate and impossible to involve leading Nigerians deeply in the construction of the model. This means that our Nigerian models are incomplete in the sense that the simulation team has had relatively little interaction with decision makers thus far (see Figure 3.1, Chapter III and the accompanying discussion).

Before our model can be implemented in Nigeria, some changes would undoubtedly be necessary to more accurately evaluate policy alternatives for Nigeria, especially those for the southern part of Nigeria where the major conflict occurred. While lack of time and available data prevent our adapting the model to the current situation, some necessary steps can be suggested for updating prior to implementation. These steps can also provide an example of the general procedure which would be necessary in updating the entire model (although the changes would be expected to be much less severe in other parts of the country and the corresponding model). Even without a thorough, close-at-hand examination of the effects of the conflict, some model changes appear obvious. The population level and age distribution in the southern ecological zones would have to be modified as a result of the population migration at the beginning of the war and the death losses due to fighting or malnutrition. The conflict caused changes in acreage, age distribution and yields (due to forced neglect or destructive acts) of perennial crops which would necessitate changes in both initial acreage levels and production rates in the war zone. Similarly, the unusually heavy demands on the food crop acreage in the eastern part of the southern region may have brought slightly more acreage into production and reduced the productivity of land by reducing or eliminating the fallow period. The availability of more agricultural labor in the eastern zone may have increased productivity per acre somewhat, with more labor applied to each acre due to the lack of other opportunities. Similarly, persons living in that area may have become more apt to consider food crop self-sufficiency of higher priority than cash cropping. Until the infrastructure, transport system and marketing system operate at the pre-war status, the land allocation and crop selection behavior might be expected to be altered, perhaps dramatically. Similarly, available capital probably declined in the war zone, thereby placing a greater capital constraint on enterprise selection and modernization in the production, processing or distribution systems.

Most other impacts of the attempted secession can be expected to be indirect, being generated by those basic changes outlined above. Until the currently prevailing plant and people population levels and distributions are known and the temporary behavior changes are estimated, conclusions drawn from our present models about policy impacts in the eastern part of the southern region should be viewed with caution. While the end result of a 25-year simulation run may not be too greatly affected by such short-run phenomena, the short-run effects could be dramatic. Since other areas would probably be only indirectly affected (and perhaps not too strongly), the results of various policies for these areas probably would not be greatly disturbed by failing to consider these effects of the civil war.

The Current Stage of Development

At this point, it seems appropriate to try to draw conclusions concerning the stage of development we have reached in constructing general systems analysis computer simulation models. We now feel that the model and many of its components are ready for application. This is not to state that they are complete. Application will involve interactions between simulators and decision makers which will reveal shortcomings in the components. Such revelation will make it necessary to modify and further develop the components and model. However, the model and its components are ready for application, in the sense that application should always be expected to involve extensive field work and interaction with decision makers which will reveal needed modification and further developments of the models. This will be true whether the models reported herein are applied in Nigeria or in some other country.

It is also our conviction that the building blocks or components of our models are potentially useful in a wide variety of countries and situations. The Nigerian components of the model presented herein can be taken apart and reused to simulate and analyze other entire agricultural sectors. Our nonagricultural component itself will be generally useful in relating the agricultural economies of various countries to their nonagricultural economies. In addition to being useful in constructing models of the entire agricultural economy of different countries, the components developed and reported herein are potentially useful in designing, analyzing and evaluating programs and more detailed projects at the subagricultural sector level. Thus, the perennial crops components developed to model the Nigerian cocoa, rubber and palm subsectors have widespread applicability in modeling corresponding subsectors of other countries. These perennial crop components also have potential applications in the developed world--possibly in modeling the vineyards of California, France and Chile, and the cherry orchards of Michigan. The demographic components used for modeling the Nigerian beef herd may have many applications in other countries: they could be used to model the national cow and buffalo herds of India as well as the national beef herd of the United States. We have even speculated about the use of this component in modeling the national tractor "herd" of the United States. In short, we conclude that the components we have developed are generally applicable in many countries and in many subsectors of the agricultural sector of those countries. Such applications will inevitably involve much field work and a great deal of interaction with decision makers.

It is also our conclusion that the processes which we have modeled are so important to the countries and their decision makers that expatriot advisors themselves are inherently incapable of fully developing and applying the models. These models deal with phenomena so important that the necessary interactions between investigators and decision makers involve decisions which many countries would want to classify as secret and keep beyond the eyes of foreign advisors. Thus, while there are areas in which applications can be made by expatriot advisors and staff members, it must be recognized that full use of these models requires their mastery by indigenous personnel. In order for our Nigerian model to be fully used in Nigeria, it will have to be mastered by Nigerians and applied, further developed, modified and extended by Nigerian investigators in closer interaction with Nigerian decision makers than can or should be carried out by foreign advisors.

Costs and Requirements of Developing New Simulation Models

The personnel, computer facilities, time, supporting services and the costs associated with any application of these simulation components to a particular industry, sector or economy policy evaluation can vary substantially from case to case. Some of the major variables affecting the costs of developing and implementing simulation models include:

1. The number and variety of policy questions to be ultimately addressed by using the model, and the required detail and accuracy of the answers;

2. The complexity of the system being simulated, i.e., number of important industries and/or interactions within the system and the degree of disaggregation desired;

3. The stock of available statistical information about recent behavior in the sector under study, and prior analyses of important behavioral relationships that will necessarily be considered in the model;

4. The quantity and quality of available cooperating researchers, and government agencies, computer facilities, transportation and communication facilities in the host country;

5. The amount of time allowed to complete the development of the model.

If the focus of an administrative unit would be a region involving only a few major competitive agricultural industries or enterprises, i.e., cattle industry, two perennial crops, or a few annual crops, a simulation model similar in kind and size to the ones developed for the cattle industry or particular ecological zones in the North or South might serve the purpose. To handle this model, a computer with 20,000 words of core memory storage would probably be required, though a slightly smaller one might suffice. Combining several industries or zones in a larger regional or national model would naturally require even more storage. (As an example, our national model utilizes most of the 32,000 word core memory in a Control Data Corporation 6500.) However, individual model components would not necessarily have to be in storage simultaneously if computer memory is limiting; model components can be run sequentially, with more time involved in transferring information stored on tape, and provide the same results with some additional computer operation and computer programming cost.

The cost of developing a simulation model for a particular industry or region would be heavily dependent upon the available stock of information about the sector to be modeled. Field research is expensive and time consuming. If a moderate amount of secondary information or cooperative help from other agencies is available, one might require approximately two scientific man-years of agricultural economist, technical agriculturalist (with a quantitative bent), and system scientist time to be expended over a 6 to 9 month period before a model would be ready for its first full application (and subsequent modifications). Naturally, some of the relationships that would need to be studied would be useful in less complete policy evaluation analyses prior to the completion of the full model. Thus, some 6 to 9 month efforts could be productive in short-term policy evaluation. Assuming a cost of $40,000 per professional man-year (that includes some travel, overhead, supplies, etc.), supporting services of $15,000 (secretary, computer programming help, etc.) and computer costs of $4,000, this type of project could require a total expenditure of approximately $100,000. To the extent that much of this effort would tie in with ongoing policy evaluation work, the actual out-of-pocket cost might be substantially less than that. After the initial development cost, the costs of model updating, data acquisition and policy evaluations would not necessarily differ from current staff expenditures or may be less, but the speed and capacity for a more realistic evaluation of many new policy alternatives would be greatly enhanced.

If one were to model an entire economy corresponding to the size and complexity of the Nigerian economy, the personnel requirements would undoubtedly be less than the 10 scientific man-years expanded on our project. Because many conceptual problems have been overcome and generalized programs are now available, an expenditure of $300,000 or less would be required if U.S. costs for personnel are used. By using indigenous personnel in the model development process, the development cost would probably be cut and training of host country personnel achieved at the same time.

Prerequisites for Successful Application of the Models Presented Herein

The model and the components presented have considerable promise for sectoral analysis by such agencies as the Agency for International Development, the Food and Agricultural Organization of the United Nations, the International Bank for Reconstruction and Development and other unilateral and multilateral donor and grantor agencies. The potentials are also very great for individual countries, both the developed and underdeveloped. In this connection, it seems worthwhile to summarize some of the preconditions for successful application as we envision them at this point in time.

1. We believe that a continuing capacity to develop the general system simulation approach must be maintained. This is in addition to applications work. While we have made substantial progress in developing the approach, models and components, there is much still to do.

2. We believe that further development of the approach will be enhanced by using the simulation models now developed in applied problem situations with substantial interaction between investigators and the policy makers on real-world problems and issues.

3. We believe that command over models and components such as we have developed by persons and agencies or institutions responsible to individual groups of decision makers is essential to the full development and application of the approach. Therefore, the development of such capacities and institutional arrangements within any country or agency of application is crucial. It is important that host country capacity to apply, modify and extend these models be developed if they are to be fully utilized.

4. It will be necessary for agencies using these models to have access to substantial computer capacity if large, complex sector models are contemplated. Here the required size of the computer facility will be greatly dependent upon the complexity of the system under study, the degree of detail required, and the skill of the model development team in efficiently utilizing available facilities.

5. It would be extremely helpful if a "software library" of simulation components could be established and made accessible to users from all over the world. Initially, this software library should probably be located in the agency responsible for establishing it. If that agency is a university, which it probably will be, a point will be reached at which the service burden of managing that library will become greater than should be carried by one academic institution. At that time, it should probably pass into the hands of an international donor and grantor agency or some agency such as the proposed Institute for International Development in the Agency for International Development of the U.S. Government. Once such a software library is fully developed and procedures are established for acquisition, storage and issuing of software components, the process of developing and applying these models to planning throughout the world should be facilitated.

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