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SIMULATION APPROACH TO DEVELOPMENT PLANNING WITH NIGERIAN AND KOREAN APPLICATIONS*

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ABSTRACT

The problems of planning for economic development arise from the interplay of the political, social and economic subsystems of a developing country. These problems are characterized by the uncertainty necessarily inherent in any process of planning for the future--uncertainty necessarily inherent in any process of planning for the future--uncertainty arising both from the quantity and quality of available data and from the difficulties of forecasting how a large-scale system of complex interactive and feedback relationships will respond to policy inputs. In this paper, we discuss generalized system simulation as an approach to dealing with these problems. We view this approach as a flexible, iterative, problem-investigating process that includes problem formulation, mathematical modeling, testing and refinement of the model, and model application to problem solution--all in close consultation with decision makers. This discussion will be followed by a brief description of policy-oriented, system simulation models of the Nigerian and Korean economies. The models consist of detailed regional agricultural submodels, an aggregated national nonagricultural submodel, and components

*The work reported here was carried out by a multidisciplinary team. Other members of the team have included: D. R. Byerlee, T. W. Carroll, H. deHaen, A. N. Halter, M. L. Hayenga, J. H. Lee, G. Page, G. E. Rossmiller, and G. L. Johnson, project director.

which model population and, in the case of Nigeria, the interregional trade in food. The policy options the current models are capable of investigating include programs to modernize agricultural production and various forms of tax and commodity marketing board pricing policies. Finally, we outline how the generalized system simulation approach could be implemented within the development-planning and policy-making process and indicate some of the capabilities and limitations of the approach.

THE PROBLEM

- -m and Geiger[1] have defined development planning as:

> ...*deliberate, rational, continuous* efforts by governments to accelerate the *process* of development and to channel it into *desired* directions by means of the comprehensive and detailed *choice* of objectives and the *determination* and *allocation* of the resource necessary for their achievement.* (p. 272)

This definition of development planning implies a whole range of complex problems which have bedeviled planners. The key words (emphasized above) stress the notion that development planning is as much a political effort as it is a socioeconomic one. The basic problem which makes planning essential to the development process is the allocation of scarce resources in an uncertain environment of complex interactions among physical, social, economic, and political forces.

Two principal types of uncertainty can be identified in this context: *state uncertainty* and *process uncertainty*. State uncertainty arises from a scarcity of reliable knowledge about present and past states of the economy and of the society in general. In this situation, it is difficult to

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*Emphasis added.

identify and measure needs accurately and to define meaningful objectives. State uncertainty is basically a data problem.

Process uncertainty, on the other hand, is much more than a data problem; it is primarily a problem of understanding how the socioeconomic system operates as a *process*, as an evolving behavioral phenomenon. Certainly, in attempting to explain how the system behaves and responds to external stimuli, knowledge of past states is necessary; but it is not sufficient. Theoretical models of causal and structural relationships are also necessary. The process uncertainty problems encountered by development planners and policy makers make it extremely difficult to forecast even the *relative* (much less *absolute*) short- and long-run effects of alternative development strategies. In particular, the degree to which policies aimed at one set of economic and social phenomena may have unintended side effects ("good" or "bad") on other aspects of the society is often even more in doubt than the direct consequences. In short, even if meaningful development objectives could be defined, the optimum path to the attainment of those objectives — that is, the maximization of "goods" and the minimization of "bads"--would lie in darkness.

This suggests another problem: It is virtually impossible to define an appropriate, objective function to be optimized. The complex physical, social, economic and political interactions involved generate multiple and often conflicting development objectives which cannot all be reduced to a single interpersonally valid common denominator for inclusion in an objective function. Examples might be employment, price stability, political stability, income and income distribution, nutrition, balance of payments, growth of GDP, political participation, education, etc. Furthermore, some objectives may not even be quantifiable. In the absence of a decision rule based on mathematical optimization, then, human judgement and compromise must be used to arrive at a subjective (and political) "optimum." Therefore, planners and decision makers responsible for the allocation of scarce developmental resources need information on the many possible trade-offs among objectives under alternative policy conditions.

In this paper, we suggest the "generalized system simulation" approach as a means of dealing with these problems of development planning and policy making. Highlights of this approach, as developed and applied in Nigeria and Korea,[2,3] will be described in the next section. This will be followed, for illustrative purposes, by overviews of the simulation models developed by Michigan State University of the agricultural economies of Nigeria and Korea with the collaboration of Nigerian and Korean researchers and policy makers. Finally, we will suggest how this approach can be implemented in the development-planning and policy-making process.

THE GENERALIZED SYSTEM SIMULATION APPROACH

The formalized problem-solving process, not new to systems engineers, contains four distinct phases: specification of needs and definition of the problem, identification of a set of feasible solutions, analysis, and selection and implementation of a solution. Generalized system simulation contributes to all phases of this process with the construction of a mathematical model of the problem and the use of computer simulation techniques to generate numerical solutions of the model under various assumptions and policy conditions. The process--including problem definition and model building, testing, validation, and application--is iterative in nature rather than strictly unidirectional (Figure 1); that is, information gained at later stages may (probably will) indicate a need to return and repeat earlier stages before continuing.

Central to the whole approach are the interactions among decision makers, researchers, consultants, and modelers and simulators. These creative interactions are essential not only to properly define the most relevant development problems to be considered by planners and policy makers but also to specify meaningful policy simulation experiments and to interpret the results. As decisions are made through these interactions, both normative (dealing with values) and non-normative (positive) information will be brought to bear. Where it is felt such information is deficient, new information will be sought.

Mathematical Modeling

In modeling a socioeconomic system, we note that many of the underlying processes of that system are continuous in nature. Others, considered continuous when viewed in the aggregate, are really made up of discrete events. Examples of the former include demographic processes of populations (of people, trees or cattle) aging through time.[4] An example of the latter is the social diffusion of innovations, which may be modeled in the aggregate as a continuous diffusion model or on the micro level as the discrete decisions of individual entrepreneurs.

Continuous processes may often be described by linear and nonlinear partial and ordinary differential equations. The following oversimplified model of a demographic process--which has been used to model cocoa trees in Nigeria, fruit trees in Korea and cattle in Colombia - will illustrate this:

$$\frac{d}{dt}\underline{x}(t) = A(t)\underline{x}(t) + \underline{u}(t)$$

$$\underline{p}(t) = B(t)\underline{q}(t)$$

$$s(t) = \sum_{i=1}^{n} q_i(t)$$

where $\underline{x}(t) = [x_1(t)\ x_2(t)\ \dots\ x_n(t)]'$ is the state vector of aggregate maturation rates of the individuals of the population being modeled (trees, cattle, people, capital goods, etc.) through n stages of the individuals' life span; $\underline{u}(t) = [u_1(t)/\tau_1\ u_2(t)/\tau_2\ \dots\ u_n(t)/\tau_n]'$ is the vector of controls applied to each life stage, e.g., planting rates, investment decisions, liquidation rates, etc.:

$$\begin{bmatrix} \beta_1 - \alpha_1 - (1/\tau_1) & \beta_2\tau_2/\tau_1 & \dots & \beta_n\tau_n/\tau_1 \\ 1/\tau_2 & -\alpha_2 - (1/\tau_2) & \dots & 0 \\ 0 & 1/\tau_3 & \dots & 0 \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ 0 & \dots & 1/\tau_n & -\alpha_n - (1/\tau_n) \end{bmatrix}$$

is the (possibly) time-varying matrix of coefficients; $\beta_i(t)$, $i=1, \dots, n$, are proportional birth rates from the n life stages; $\alpha_i(t)$, $i=1, \dots, n$, are proportional attrition rates (due to deaths, sales, etc.); τ_i, $i=1, \dots, n$, are *mean* maturation times for each of the n life stages; s(t) is the total number of individuals in the population; $\underline{q}(t) = [\tau_1 x_1\ \tau_2 x_2\ \dots \tau_n x_n]'$ is the vector of the number of individuals in each life stage; $\underline{p}(t)$ is the output vector of variables which depend upon the age distribution of the population, e.g., production from trees, capital goods or livestock, or social services demanded by a human population; and B(t) is the "input/output" matrix.

This model is actually a lumped approximation to a distributed parameter process--the aging of the individuals of a population--which would otherwise be modeled with partial differential equations.(5) That is, a continuous age distribution is lumped into n stages or cohorts. The number of stages n and the time constants τ_i, i=1, ..., n, are chosen to give a good fit to the probability density function that describes the random life span of individuals. This model structure realistically handles the fact that all individuals in a aggregate population (the state variables are *aggregative variables*) do not mature at the same rate.(6)

In general, development models must contain both continuous time and discrete time variables (actions of decision makers at micro and macro levels tend to be discrete in time). It has been found appropriate to obtain particular solutions for these large, usually nonlinear, continuous/discrete time models with a digital simulation approach. The approach solves the differential equations of continuous processes by using numerical integration techniques to convert them to difference equations, and the difference equations of discrete time phenomena are readily handled as is. In most cases it has thus been possible to structure the entire simulation model in terms of recursive first-order difference equations.

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

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

$$\underline{\pi}(t) = \underline{G}[\,\underline{\psi}(t),\ \underline{\alpha}(t),\ \underline{\beta}(t),\ \underline{\gamma}(t)]$$

where:

$\underline{\psi}(t)$ = a vector of variables defining the state of the simulated system at any given time. State variables may include such quantities as production capacities, prices, population by subgroups, levels of technology, etc.

$\underline{\pi}(t)$ = a vector of output variables, including such performance measures as profit, income, growth rates, balance of trade, employment, etc.

$\underline{\alpha}(t)$ = a vector of parameters defining the structure of the system. These usually involve rates of change of variables between levels and input-output coefficients, such as technical coefficients, behavioral response parameters, price elasticities, migration rates, birth and death rates, etc.

$\underline{\beta}(t)$ = a vector of environmental variables, such as world prices, weather, etc.

$\underline{\gamma}(t)$ = a vector of policy instruments, such as tax policies, production campaigns, investment alternatives, etc.

This general formulation is realized in the hundreds or even thousands of parameters and structural relationships (depending on the size of the model) actually incorporated in the simulation model. Specifications of the model, given the problem definition, requires a multidisciplinary team composed of: 1) policy makers as clientele to insure the model is relevant to their needs and incorporates their perspective; 2) subject matter specialists from appropriate disciplines (e.g., agricultural economists, sociologists, agronomists, etc.) to provide the necessary theoretical and empirical data upon which to base the model; and 3) systems scientists with the necessary mathematical and systems engineering skills to put it all together into a reliable, working model. Such multidisciplinary teams were used in constructing the Nigerian and Korean models discussed in later sections.

Testing, Validation and Policy Application

Model testing, refinement and validation are closely linked processes. A simulation model is tested both to check its internal consistency and to assure that it is an adequate representation of the real economic system (adequate for the purposes at hand as stated in the problem definition). Tests may include such activities as tuning the model to track recorded time series, conducting sensitivity tests on model parameters and subjecting the simulated system to exogenous shocks or disturbances and observing the consequent responses. Test results will suggest refinements and modifications to be made in system structures and parameter values and will indicate areas where better data are most needed.

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. As long as the decision maker is aware of the model's limitations,perfect validity is not necessary. Indeed, perfect validity--in the sense of perfect information on the future behavior of the real system under various assumed conditions--is not attainable.

The most important reason for developing a simulation model (in this context) is to provide a laboratory for exploring the consequences of a wide range of alternative plans or management strategies. This is an iterative process involving close interaction among decision makers and system analysts. One simulation experiment can lead to the creative design of a new and better one which may involve reprogramming or even basic modifications of the model. The objective of such simulation experiments is to unfold a set of development strategies that are consistent, mutually reinforcing and show how resources could be effectively used to solve the basic problem (as defined).

THE NIGERIAN MODEL

Utilizing the generalized system simulation approach described in the last section, a preliminary, planning-oriented simulation model of the Nigerian agricultural economy has been developed.* A broad description of this model and its policy orientation follows. More detailed discussions of the mathematical model and its potential applications may be found elsewhere.[2, 4, 5, 7]

The Model

The Nigerian model is composed of three major submodels: the northern regional agricultural submodel, the southern regional agricultural submodel and the nonagricultural/national accounts submodel. In addition, there are components which model the national food market and the population. Figure 2 indicates the major interactions of these submodels as well as the principal inputs and outputs of the system.

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To permit considerations of simple questions related to regional specialization and interregional trade, a two-region (North and South) commodity-oriented model was conceived. In addition, several ecological zones within each region were differentiated to permit more detailed consideration of intraregional problems. Although the model is based on Nigeria, its orientation toward cattle and both annual and perennial commodities with distinct ecological zones and regions makes its components adaptable to a broad range of countries. Indeed, building blocks of the Nigerian model have been adapted and used in Korea, Venezuela and Colombia

The basic component structures of the two regional agricultural submodels are quite similar. (The Northern submodel is shown in Figure 3.) The nature of perennial commodities, however---trees exhibiting such characteristics of dynamic populations as gestation, growth, maturity and decline--considerably complicates the southern submodel, particularly in the land allocation and modernization component, where the population dynamics of trees are modeled (as discussed above) as a distributed parameter process.[5]

Briefly, the agricultural submodels allocate land to the available commodities based on profitabilities perceived by farmers and subject to input constraints. From the land allocations, and given commodity yields and other technological coefficients (e.g., factor input rates, marketing losses, etc.), the total production of each commodity is determined, and marketing and processing functions are performed. Agricultural processing in the North is modeled with input-output ratios, while in the South, because of the significance of palm and rubber processing activities to the agricultural producers themselves, processing is modeled in greater detail. Finally, economic performance criteria are generated and the agricultural sector accounts are balanced for each region.

An additional component of the northern submodel, 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 grazing and from the production of forage and grain corps. The main interactions between the cattle and annual crops components in the northern submodel occur in the land allocation component where crop land competes with grazing land and in the production component where crop residues contribute to the TDN available to the cattle population.

The nonagricultural submodel is an aggregated, ten-sector input-output model of the Nigerian economy. One of the ten sectors, the agricultural sector, is modeled in detail on the micro level by the agricultural submodels, while the nine nonagricultural sectors are aggregated on the macro level. Since the primary focus of the national model is agriculture, the broad, aggregated nonagricultural submodel enables the investigation of key interactions between agriculture and nonagriculture, e.g., agriculture's demands for consumer goods and capital inputs, nonagriculture's demands for raw materials and food, and rural-urban migration --and how the interactions are affected by, and in turn feed back to affect, the results of agricultural development policies. This submodel also constructs the national accounts, including measures of gross domestic product, consumption, investment, government revenues and import-export balances.

Two additional components act on the national level. The populatio component simulates (for each region) births, deaths, and the aging of a population lumped into 27 three-year age cohorts. In addition, the tota labor force is determined and split between agricultural and nonagricultural occupations in each region and each ecological zone, and rural and urban food demands are computed. The market and interregional trade component models the national food market. It takes cash food supplies from the agricultural submodels and food demands from the population component, computes the price of transportation (based on investments in transport capacity) and interregional shipments of food, and thus determines the market price of food in each region.

Policy Orientation

In this work, effective problem definition required creative interaction among decision makers, planners, systems analysts, agricultural economists and other specialists. The interdisciplinary research team at Michigan State University was fortunate in having available professionals with a backlog of experience in the Nigerian agricultural economy. Previous collaborations with AID, FAO, and Nigerian planners and policy makers provided us with 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 model's planning clientele, the major policy questions and the corresponding relevant sectors, interrelationships, and variables in the Nigerian economy were identified and isolated more easily than they might otherwise have been.

Policy inputs to the agricultural submodels are of three types: 1) production campaigns aimed at modernizing agricultural production, including cattle as well as annual and perennial crops; 2) commodity marketing board producer price-setting policies which either may generate board surpluses to be used for price stabilization or to finance development projects or may directly benefit farmers with higher producer prices; and 3) income and export tax policies. Other kinds of policy instruments could be added, but the three included were seen to be both of interest to Nigerian policy makers at the time the model was defined and general enough to be relevant to other countries of the developing world. Indeed, the consideration of other polic--- should be added to the model as time goes on if it is to remain relevant and useful in a changing world.

Although the Nigerian simulation model was built, under terms of the AID contract, for methodological purposes rather than for actual application, planners and decision makers in Nigeria's Federal Ministry of Agriculture and Natural Resources (FMANR) and their consultants in Nigerian universities have used the model on two occasions to make policy experiments. On the second occasion, two series of runs were made, one of 17 runs testing combinations of crop production campaigns with input constraints and various marketing board and export tax policies, the other of five runs investigating alternative cattle production policies. The results of these simulations were analyzed and evaluated by Nigerian officals and were incorporated in a report constituting the FMANR's contribution to Nigeria's Third Development Plan, to be launched in 1975.

While the Nigerian applications have not (yet) been directly responsible for any actual policy implementations, an application of one component of the Nigerian model on another continent has been. The Nigerian cattle model was adapted and used in Venezuela to investigate problems in that country's cattle industry.[8] The model proved highly credible in the eyes of Venezuelan policy makers, and a dramatic turn-around in Venezuela's cattle policies (in 1972) was directly attributed, in part, to results of the simulation analyses.

THE KOREAN MODEL

Under contracts with the U. S. Agency for International Development* a Michigan State University/Korean team was charged with the responsibility of developing and applying a simulation model for evaluating alternative strategies for rural development in the Republic of Korea. While the development of such a model is a large task requiring a number of years, model results were required within one year as inputs to the decision-making processes.[3] This dictated a model development strategy which included a short-run effort culminating in a preliminary model capable of producing the required short term results and a longer run modeling activity to refine and expand the preliminary model. In what follows we will describe the preliminary model, extensions and refinements which are currently underway, and a summary of results obtained from this first iteration model.

The Preliminary Model

During the first year of the study with the Korean government, attention was focused on several alternative strategies for [illegible] development of the country. Initially, the preliminary simulation model was used to

*AID/csd-2975 and AID/ead-184

project the consequences through time of pursuing each of three strategies. These computer results were then evaluated by decision makers and were used in the synthesis of a fourth strategy considered by decision makers to be "better" than the initial three. This fourth strategy becai the strategy recommended by the MSU/Korean team of investigators at the end of the first year of the study. The initial three strategies evaluateu by the preliminary simulation are broadly described as follows:*

1) a set of policies which accept the goals of the Third Five-Year Development Plan (TFYP) and follow the course outlined by the plan through 1985. (The TFYP had as major goals national self-sufficiency in food and a narrowing of the income gap between rural people and the increasingly affluent city dwellers. To attain these goals the TFYP programmed extensive investments to increase agricultural production and relatively high domestic prices of food.)

2) a set of policies which accept the goals of the TFYP but pursue them more vigorously in terms of level of investment, allocation of investment by category, and modified food price policies to further stimulate production and increase self-sufficiency by modifying the structure of demand.

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*Alternative IV will be briefly described below in the discussion of results.

3) a set of policies which constitute a "free trade" alternative. This alternative abandoned the goal of food self-sufficiency and investigated some of the consequences of allowing world markets to determine domestic prices for food and agricultural production inputs.

With this as background, we will broadly discuss the preliminary model and how it simulated the consequences of following these three management strategies.

As shown in Figure 4 the preliminary model disaggregates production into 19 commodities or commodity groups.* On the production side, the model is disaggregated according to three regions within the country, with regions defined according to cropping patterns which are determined fundamentally by climatic and topological factors. The model disaggregates consumption of agricultural products according to the 19 crops or crop groups mentioned above and also according to a rural/urban classification. Agricultural supply is thus computed as the difference between production and farm consumption plus losses (by items). Rural consumption by item is computed as a function of agricultural income, producer prices, agricultural population and the nutritional requirements of the agricultural population as influenced by age and sex distribution. The latter are computed by the population component of the model while agricultural income is computed by the production component. The determination of model prices will be discussed later.

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*They are: (1) rice, (2) barley, (3) wheat, (4) other grains, (5) fruits, (6) pulses, (7) vegetables, (8) potatoes, (9) tobacco, (10) forage, (11) silk, (12) industrial crops, (13) beef, (14) milk, (15) pork, (16) chicken, (17) eggs, (18) fish, and (19) agricultural residual.

Urban consumption of the 19 food items is computed for the urban population by the urban demand model shown in Figure 4. This model component also computes the demand of urban people for nonagricultural goods and services and interactions between agricultural and nonagricultural demands as influenced by growth in total urban income, urban population, and food prices. The urban demand model receives, as time varying inputs, urban population from the population component and total consumption from a macro model of the nonagricultural economy.

The population migration component in Figure 4 is a linear, discrete-time state model of the form

$$\underline{P}(t+1) = \underline{A}(t)\,\underline{P}(t) + \underline{M}(e_u, t).$$

Here $\underline{P}$ is a 160 x 1 vector of population cohorts (40 two-year age classes for rural and urban males and females). The matrix $\underline{A}$ provides for normal aging transitions and time-variant death and birth rates. The latter are functions of government family planning policies. The migration vector $\underline{M}$ is a function of urban employment opportunities e_u. The assumption in the first iteration model was essentially that rural people of appropriate age/sex classes would migrate whenever urban employment opportunities became available.

As indicated in the figure, the model used in making projections contains a partial model of agricultural production. The production component is partial in the sense that a number of variables which eventually will be endogenous must now be supplied exogenously. These include crop yields* over time as they are influenced by the three policy alternatives and land areas allocated to enterprises (by regions) by an iterative process to be described.

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*Metric tons per hectare

Yield projections for the three policy alternatives were made on the basis of research and field data, estimation of the impacts of government programs to promote improved technology, and trend information. Projections of total arable land by region were made, including the effects of urbanization and programs to expand agricultural land area. Agricultural price inputs to the production model are determined by policies and supply/demand interactions. This component receives agricultural population and labor force from the population/migration model. Given these as major inputs, the production model computes a number of variables including the following: total production by enterprise and region; seasonal production, as during harvest season; seasonal labor requirements; farm consumption and storage of output; sales (supply); gross income by crop (region specific), by region and by sector as a whole; demands for and expenditures on inputs by type (fertilizer, chemicals, capital, labor, etc.) by crop, region and sector; gross profit by enterprise and region; returns above land and labor, to land and labor, by crop by region; gross income per capita by region; and per capita rural intake of calories and protein.

We will now describe the iterative approach used to make agricultural sector projections with this model. The approach, used for each alternative management strategy in turn, will be described as it was applied to specific alternatives. To begin the iterative process, the following variables are supplied as exogenous variables to the model structure shown in Figure 4:

1. Grain prices (rice, barley, wheat) for 1970, '75, '80, '85 as determined by policy for the particular alternative.

2. A tentative set of prices for commodities with prices determined by domestic supply and demand.

3. A projection of total urban consumption for 1970, '75, '80, '85 (Won/yr). (Consistent with Third Five-Year Plan projections, urban consumption is initially assumed to grow at 9 percent under the three alternatives).

4. Yield projections (MT/ha) by enterprise, 1970, '75, '80, '85.

5. Projections of total arable land by regions, 1970, '75, '80, '85.

6. A tentative allocation of land area to crops by region, 1970, '75, '80, '85.

Given these inputs, the model shown in Figure 4 was run through time from 1975 to 1985. In addition to the criterion or performance variables, the model computed over time a number of variables needed for further iterations of the process being described. These variables included:

1. Domestic deficits and surpluses (MT/yr) by commodity by year.

2. Average producer returns per hectare and per man-year by commodity by year.

3. Agricultural sector value added by year.

The first two variables were used to make changes in commodity prices and crop area allocations for subsequent iterations. Specifically, nonpolicy determined prices were adjusted upward or downward as a function of net excess demand.* Land was reallocated on the basis of relative crop profitabilities, available arable land in each region and constraints imposed by regional cropping systems. This iterative process was continued on the first two variables until supply-demand equilibrium was approximately established over the time interval, 1970-85.

Given this equilibrium it was possible to carry out iterations between the agricultural and nonagricultural models to correct for any significant changes in urban demand for agricultural commodities due to changes in agricultural imports, exports, and value added away from the values used to make initial projections of nonagricultural consumption. These iterations were not important in Korea where agricultural income and value added are a relatively small proportion of national aggregates (about 27 percent in 1970 and 18 percent in 1985).

Some Results from the Preliminary Korean Model

Typical output from this iterative process using the preliminary Korean simulation model is shown in Table 1 for alternatives I and IV. While just a fraction of the information the model is capable of providing, the table contains some of the variables which are of major interest to decision makers. The table indicates values of the tabulated variables at 5-year intervals from 1970-85 (the model can provide data for all variables

*In later versions of the model, the model computes these prices endogenously without iteration.

at yearly intervals if desired and for certain variables at sub-yearly intervals). Recall that alternative I is essentially the course Korea was following at the time the study was initiated (1971) and that alternative IV is the recommendation of the MSU team based on interactions with decision makers involving, among other considerations, an analysis of the capabilities and limitations of Alternatives I, II, and III. Alternative IV emphasized higher prices to farmers and substantial increases in public investments in rural development. The primary advantages of alternative IV in the view of decision makers were a marked reduction in imported food for Korean people (item 28 in Table 1), and an improved standard of living for rural people (items 15-20 in Table 1). The major disadvantages of alternative IV were a modest increase in the urban price index (item 8), a net decrease in urban well-being as measured by non-food consumption (item 10) and an increase in the level of public investment in rural development (not tabulated).

To date some, but not all, of the policy recommendations contained in alternative IV have been implemented by decision makers. These include higher prices to farmers, particularly for grains, and increased public investment in certain rural development programs. The fact that alternative IV was not implemented as postulated and the effects of random disturbances (weather, world grain price change, energy price increases, etc.) upon system variables make model verification on the basis of this one experience tenuous at best. Since the conclusion of the one-year study and associated model application, the original model has been used by the Korean government to do analysis and projections in the formulation of the Fourth Five-Year Plan (1977-1981).

Refinements and Extensions of the Preliminary Korean Model

Since the completion of the preliminary model and its use described above, a number of refinements and extensions have been undertaken. A major refinement has been the development of a large linear programming model to simulate the allocation of resources (land, labor, and capital) to the 19 production commodities in the three regions of the model. This model simulates the behavior of private decision makers and, if tests indicate that this approach is feasible, will replace the iterative scheme described above for allocating private resources to production activities. At the present time this model is being merged and tested with the simulation model shown in Figure 4.

A major extension to the preliminary model is a grain management component. This submodel allows the user to explore some extremely important management questions relating to government controls which affect grain prices, price stability, government stock levels, grain imports, costs of government grain management programs, foreign exchange deficits, rural income and a number of other variables. An application of modern control theory is being explored to achieve noninteractive control of rice, barley and wheat prices. Optimal control schemes are also being explored as means of simulating the way private entrepreneurs of the country speculate in the purchase and sale of grains.

As time goes on, other refinements and extensions will be desirable for improving the capability of the model to address relevant management questions. These include refinement of the linkages with an improved model of the nonagricultural sector, including more behavioral variables in the relationships which determine rural-urban migration and improvement of the relationships which determine private consumption, savings, and investment.

IMPLEMENTATION

The ultimate objective of developing simulation models such as described above is to implement them as an integral part of the general problem-solving process outlined earlier (Figure 1).

Experience with actual applications of the Nigerian, Korean and related models described above has shown that even in their preliminary forms the models are useful for analyses of the specific policies (e.g., production campaigns and price and tax policies) and the specific problem areas (crops and livestock) for which they were designed.[2, 3, 8] However, there are many relevant policies and problem areas--elsewhere in agriculture and in nonagriculture--which were necessarily excluded from the scope of these models. These range all the way from the very micro (e.g., farm decision units as producer firms and consumer households) to the very macro (e.g., general inflation). Development being an evolutionary process, the concerns of planners and policy makers will range over this whole spectrum of problem areas with emphasis changing over time.

Since no single model can hope to economically cover everything of current and potential relevance to policy makers--because of limitations of human and computer resources--implementation of the system simulation approach as described in this paper would probably require the development and use of a hierarchical "library" of generalized models. Models would be selected from the library at various levels of aggregation and used in concert as appropriate for a specific application; that is, one or more disaggregate models would be chosen to consider interactions within the problem area and with related areas, and more aggregate models would be chosen to cover the rest of the economy.

A number of preconditions may be envisioned for successful application of the approach to problems in the developing countries. These include, in addition to the software "library", trained professionals (from a number of disciplines) capable of developing and maintaining models; modern medium-to-large scale computers; and an institutional framework within which the models can be used interactively as part of the decision-making processes. In most countries one or more of these preconditions is missing. Clearly, model implementation is itself a "systems" problem that requires a holistic approach to organization and the allocation of resources.

CONCLUSIONS

As workers in the development of models for application to complex economic and social problems, we are painfully aware of the inadequacies of our models and approach. These models contain many simplifying assumptions, omit many important factors which are difficult or impossible to quantify, usually include inadequate data and are very difficult to validate. (Validation of these models to date has been based on extensive tests for logical consistency and tests against historical data generated by the real world[2]). In spite of these limitations, our experience as a team of researchers has led us to believe that well-conceived models can be useful to decision makers who are forced to make exceedingly complex decisions with or without the aid of formal models and that such models are often worth building. The following paragraphs discuss some of the reasons for this conclusion.

The system simulation approach, as part of the problem-solving process (Figure 1), can provide important contributions to three broad aspects of development planning and policy making: understanding the socioeconomic system, formulating development policies, and focusing research activities. These aspects are somewhat overlapping; for example, both research and an increased understanding of the problem certainly contribute to improved policy formulations.

Detailed analyses of the behavior of a simulation model of the system under a range of data and structural assumptions and policy conditions provide a comprehensive view of the complex and dynamic socioeconomic system under study. This, combined with the model-building process itself--particularly the identification of causal and structural relationships--can contribute substantially to an improved understanding of, and sharpened intuitions regarding, the development process in general as well as the particular socioeconomic system of concern. For example, sensitivity tests will pinpoint sensitive parameters, and the analyses carried out to explain the simulated consequences of parameter changes will highlight complex interactions of the simulated system.(5) Insofar as the simulated system faithfully represents relevant behavioral patterns of the real system, the heightened understanding can be a valuable asset in reducing some of the uncertainty policy makers necessarily face.

A more direct input to the policy-making process is the capability of a generalized system simulation model to explore the consequences and implications of a wide range of development policy options by projecting time paths of relevant output variables under alternative combinations of policies. Using the same data as is available for other approaches and techniques, the model takes account of many more complex policies and interactions than can be done by hand or with models necessarily simplified by the constraints of the specialized techniques used. In this way, a good deal of the uncertainty concerning the system's direct and indirect responses to various policies can be reduced. Another important application of such a model to policy formulation is in dealing with the uncertainty inherent in the quality of the available data. Sensitivity tests, where key parameters are varied in each of a number of alternative policy situations, can be used to evaluate the sensitivity of policies to data uncertainty. Alternatively, the model can be run in a Monte Carlo mode where uncertain parameters are assigned probability distributions, a number of runs are made with observations from those distributions, and output statistics are generated. This is information essential in the search for stable policies, that is, policies which will have the intended results even though projections were based on poor data.[2]

A third contribution the system simulation approach can make to development planning is as a focus for research activities. There are primarily three ways in which use of a simulation model can provide a central theme to coordinate and guide research. First, sensitivity analyses will suggest data collection priorities to improve the available estimates of the most sensitive parameters and coefficients of the model. Secondly, the model's application will motivate investigations into structural relationships among, and the behavior of, component elements of the socio-economic system. These efforts will be necessary to provide theoretical models for the continual improvement and updating of the simulation model's (or models', in the case of a library) assumptions and representations of the real system and to keep it (them) relevant to the needs and concerns of policy makers in a changing world. Finally, technological research may be suggested by policy runs speculating on the likely consequences of the introduction of an innovation which may not actually be developed at the moment. Of course, the projected consequences would have to indicate that the expense of undertaking such research and development was warranted.

As regards the construction and use of libraries of models, the Nigerian and Korean models indicate how generalized models can be built and then assembled as needed for application to a particular problem situation in a particular country. Components of the Nigerian and Korean models as presented here can be taken apart and reused to simulate and analyze other entire agricultural sectors or subsectors.(8) The nonagricultural component of the Nigerian model can be generally useful in relating the agricultural economies of various countries to their nonagricultural economies. Some of the Nigerian components have already found application in Korea(3) and some of the Korean components have been found applicable in Tanzania.

In conclusion, the generalized system simulation approach can, given a "critical mass" of data and information about the socio-economic system*, be a useful and valuable tool in coping with uncertainty in the development-planning process, providing a comprehensive view of a complex, dynamic

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*It is our judgment that a "critical mass" was available, or obtainable at reasonable cost, in Nigeria and Korea. This will not always be the case in lesser developed countries.

system while at the same time facilitating policy experimentation and motivating research. The approach is characterized by high initial costs (reflecting the costs of data acquisition and modeling) but relatively low recurrent costs as models are used to explore a myriad of policy options. It must be remembered, however, that simulation models, while potentially an integral and important part of the decision-making process, will not replace the decison maker. They will, however, give him more information, help to identify new and economically feasible policy options, and sharpen his intuition--thus making for better decisions.

REFERENCES

(1) Colm, Gerhard and Theodore Geiger, "Country Programming as a Guide to Development" in Robert E. Asher, ed., Development of the Emerging Countries: An Agenda for Research (The Brookings Institution, 1962).

*(2) Manetsch, Thomas J., et al., A Generalized Simulation Approach to Agricultural Sector Analysis With Special Reference to Nigeria (East Lansing: Michigan State University, November 30, 1971).

*(3) Rossmiller, George E., et al., Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985, Project Report, Michigan State University, July 1, 1972.

(4) Abkin, Michael H. and Thomas J. Manetsch, "A Development Planning-Oriented, Simulation Model of the Agricultural Economy of Southern Nigeria," IEEE Transactions on Systems, Man and Cybernetics, 2:472-486, September 1972.

(5) Abkin, Michael H., Policy Making for Economic Development: A System Simulation Model of the Agricultural Economy of Southern Nigeria, unpublished Ph.D. dissertation, Michigan State University, 1972.

(6) Manetsch, Thomas J., "Transfer Function Representation of the Aggregate Behavior of a Class of Economic Processes," IEEE Transactions on Automatic Control, AC-11:693-698, October 1966.

(7) Manetsch, Thomas J., Marvin L. Hayenga and Albert N. Halter, "Simulation of Nigerian Development: Northern Region Model," IEEE Transactions on Systems, Man and Cybernetics, 1:31-43, Jan. 1971.

(8) Miller, S. F. and A. N. Halter, "System-Simulation in a Practical Policy-Making Setting: The Venezuelan Cattle Industry," American Journal of Agricultural Economics, 55:420-432, August 1973.

*These reports are available from the authors.

	Consequences	Units	1970		1975		1980		1985	
			Alt I	Alt IV	Alt I	Alt IV	Alt I	Alt IV	Alt I	Alt IV
1	Population Total	1000 Per.	31690.	31690.	34673.	34632.	37608.	37180.	40898.	39478.
2	Population Urban	1000 Per.	15820.	15820.	19209.	19186.	24522.	24253.	31853.	30810.
3	Population Rural	1000 Per.	15870.	15870.	15464.	15446.	13086.	12927.	9046.	8668.
4	Calories Rural (Reg. 2)	Cal/Cap-Day	2630.	2630.	2620.	2602.	2680.	2676.	2747.	2787.
5	Calories Urban	Cal/Cap-Day	2536.	2536.	2723.	2578.	2794.	2698.	2854.	2747.
6	Protein Rural (Reg. 2)	Grams/Cap-Day	65.	65.	65.	65.	68.	70.	74.	78.
7	Protein Urban	Grams/Cap-Day	72.	72.	82.	78.	87.	86.	91.	90.
8	Urban Consumer Price Index	1970=100	100.	100.	103.	109.	103.	108.	103.	108.
9	Urban Nonfood Expenditure Total	Bil. Won	858.	858.	1407.	1310.	2358.	2230.	3870.	3669.
10	Urban Nonfood Expenditure PC	1000 Won/Cap	54.	54.	73.	68.	96.	92.	121.	119.
11	Urban Food Expenditure Total	Bil. Won	592.	592.	867.	964.	1208.	1336.	1723.	1925.
12	Urban Food Expenditure PC	1000 Won/Cap	37.	37.	45.	50.	49.	55.	54.	62.
13	Total Urban Expenditure	Bil. Won	1450.	1450.	2274.	2274.	3566.	3566.	5593.	5593.
14	Food/Total	Percent	40.8	40.8	38.1	42.4	33.9	37.5	30.8	34.4
15	Gross Ag. Income (Agr. + Other)	Bil. Won	619.	619.	1028.	1218.	1157.	1406.	1376.	1653.
16	Gross Ag. Income PC (Agr. + Other)	1000 Won/Cap	39.0	39.0	65.8	78.	84.0	102.9	138.8	172.7
17	Ag Value Added Total	Bil. Won	509.	509.	698.	886.	796.	1038.	934.	1210.
18	Ag Value Added PC	1000 Won/Cap	32.1	32.1	44.7	56.7	57.8	76.	94.3	126.4
19	Returns Per Ha. (rice, Reg. 2)	1000 Won/Ha	147.	147.	209.	321.	215.	355.	205.	364.
20	Returns Per Man-Yr (rice, Reg. 2)	1000 Won/Man-Yr	210.	210.	290.	436.	295.	465.	276.	462.
21	Fertilizer Required	Mil. Mt	.77	.77	1.15	1.39	1.35	1.87	1.61	2.2
22	Pesticide Index	1970=100	100.	100.	120.	121.	146.	146.	174.	175.
23	Capital Required Index	1970=100	100.	100.	146.	162.	196.	212.	402.	430.
24	Expenditure on Fertilizer	Bil. Won	17.8	17.8	22.4	27.1	23.2	32.3	24.0	33.4
25	Expenditure on Pesticide	Bil. Won	6.9	6.9	6.4	6.4	5.9	5.9	5.4	5.4
26	Expenditure on Capital	Bil. Won	35.1	35.1	44.9	49.9	53.0	57.3	95.9	102.6
27	Taxes Paid Index	1970=100	100.	100.	156.	204.	185.	252.	230.	302.
28	Value of Ag. Imports (Less FG)	Bil. Won	90.	90.	109.	77.	180.	103.	259.	140.
29	Value of Ag. Exports	Bil. Won	14.	14.	48.	53.	74.	88.	105.	115.
30	Net Export (Export-Import)	Bil. Won	-68.	-68.	-61.	-24.	-106.	-14.	-153.	-26.

TABLE 1: **Projected Consequences for Alternatives I and IV, 1970-1985 (Korean Agricultural Sector Model)**

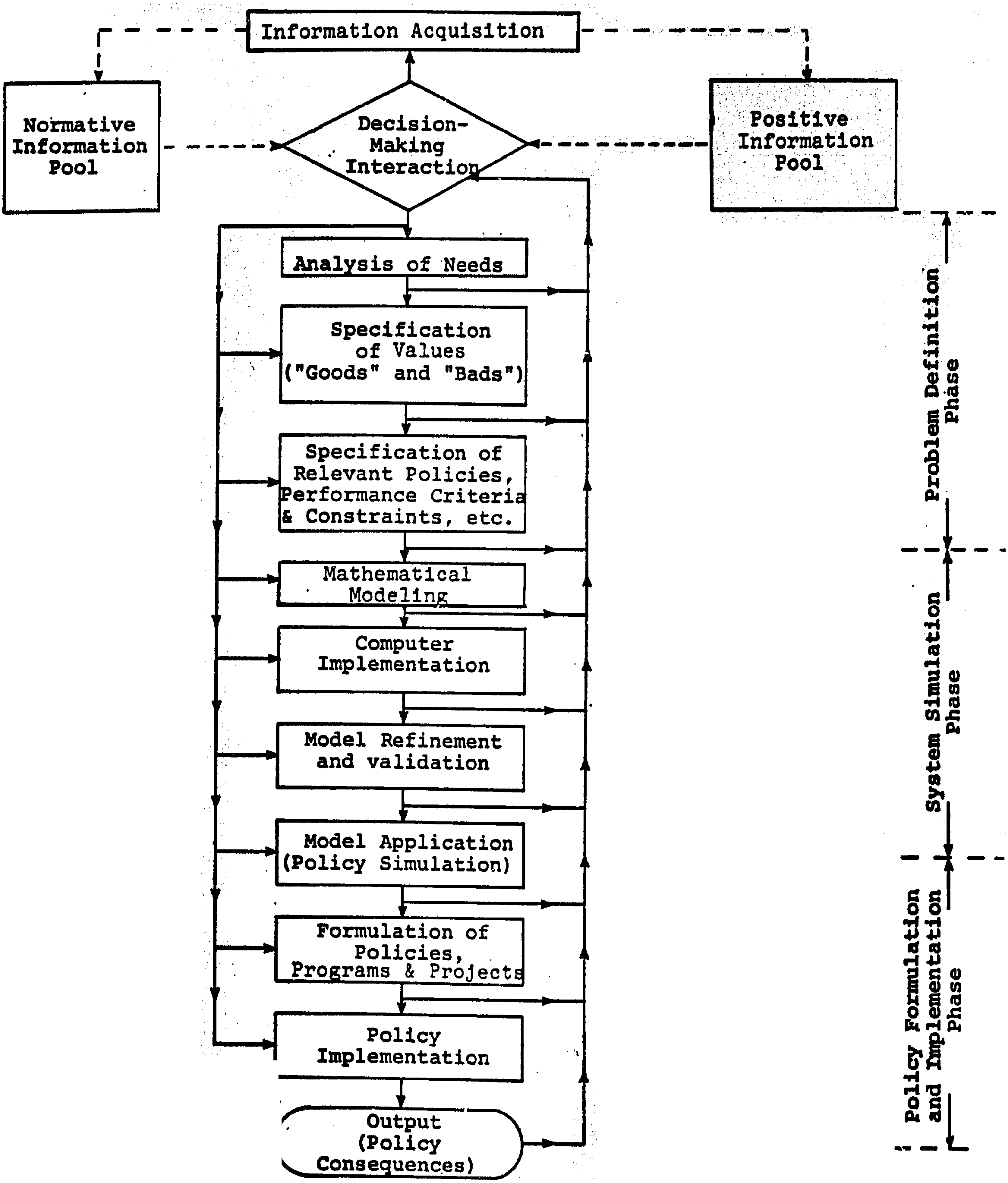

Figure 1
System Simulation and the Policy-Making Process

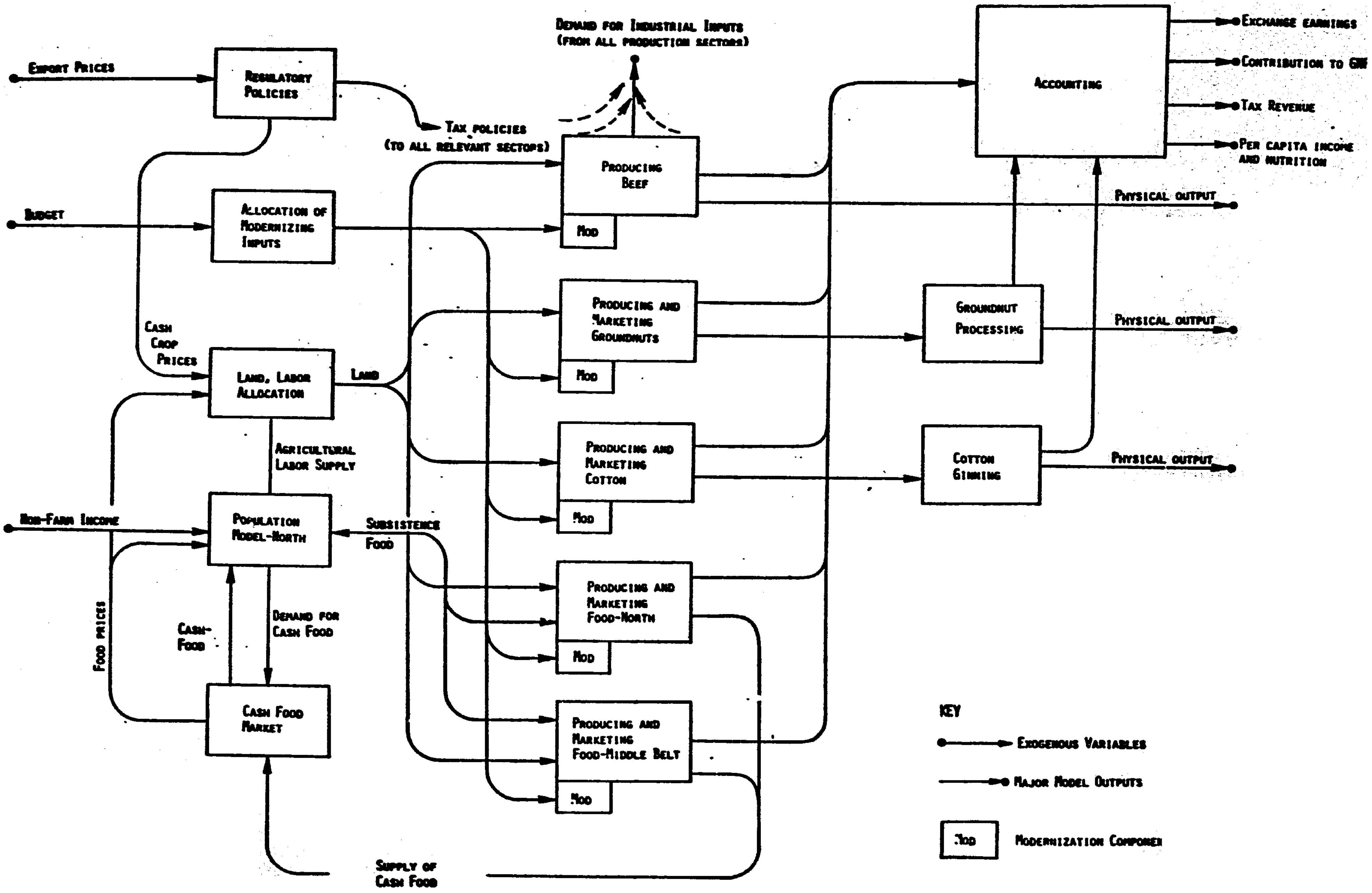

Figure 3. Major sectors and interactions of the northern Nigerian agricultural model.

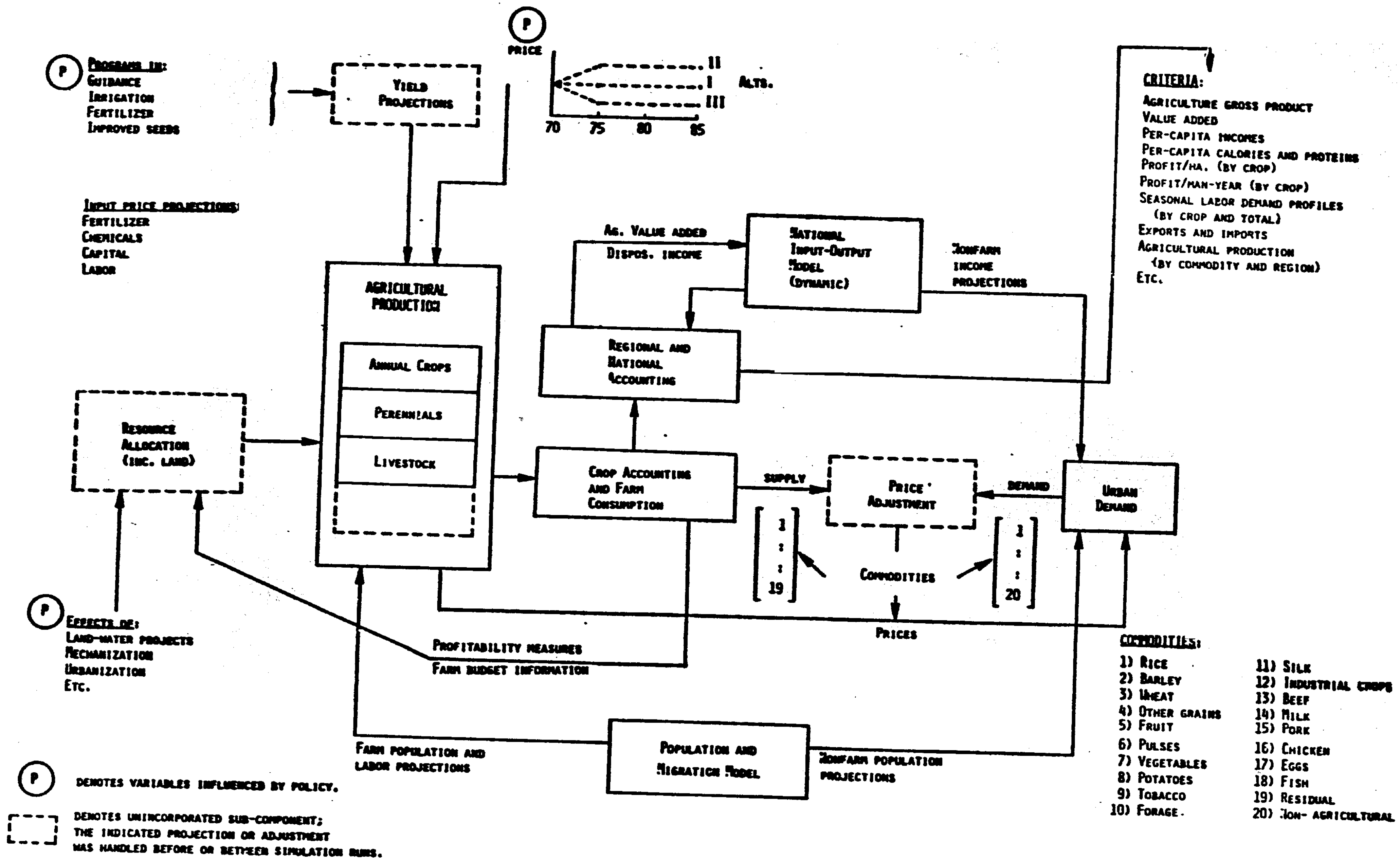

Figure 4. Diagram of the preliminary model of the Korean agricultural sector used to project consequences of alternative policy strategies.