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THE GENERAL SYSTEMS-ANALYSIS APPROACH FOR AGRICULTURAL SECTOR ANALYSIS: ABILITY TO HANDLE VARIOUS CONTRIBUTING TECHNIQUES

Discussion Paper

by

Hartwig deHaen

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1. Introduction

In their recent publication, "A Generalized Simulation Approach to Agricultural Sector Analysis," Manetsch, et. al. [19] mention as one of the important characteristics of their approach the flexibility "with respect to (1) types and sources of data, (2) estimation and approximatie procedures, and (3) techniques." [19, p. 25] The authors regard all specialized techniques as potential contributions to their approach, including, for instance, LP, NLP, equilibrium simultaneous equations, input-output analysis, cost-benefit analysis or project evaluation and review techniques (PERT). It is this flexibility to handle various techniques which will be discussed in this paper.

Obviously, the development process is rather diverse. It is affected by various economic, social and political variables with decisions being made on various levels and under different objectives and degrees of information. Therefore, it may seem reasonable to model this process with a similar diversity in the methodology and thus to select appropriate techniques for each of the components within the system individually. The following paper will--after a brief review of existing approaches and techniques--discuss how the overall system can be broken into separately manageable components. It will then investigate, given the objectives of agricultural sector analys what kind of components may be appropriate and by what techniques they should be modeled. Finally, some remarks will be made with respect to the practical implementation and computation of a multicomponent approach including various specialized techniques.

2. Review of Existing Approaches to Sector Analysis with Respect to the Techniques Involved.

Some introductory remarks on simulation and on the economic theoretical background of the general systems approach as compared to other concepts for sector analysis, will be made before the ability to handle several techniques is discussed.

The economic models which have been designed and quantitatively tested during the last 10 to 15 years in order to improve the understanding of socio-economic systems and their behavior with respect to alternative policies have become increasingly complex. They often include nonlinearities, random variables, partial difference or differential equations and they are often quite large. It would, therefore, be impossible to compute the values of the systems response variables for various points in time (solution) analytically. Instead of that, simulation as an iterative procedure to compute the levels of the response variables for consecutive time periods, has been widely applied. The general systems analysis approach is based on the simulation concept. The following review will, therefore, include primarily those approaches which are based on this concept.

The various applications of quantitative studies for sector analysis may be categorized according to two criteria. The first is the level of aggregation and the character of the economic, social and political problems which are investigated. The second is the methodological concept and the kind of techniques which are used in the different studies. Although both criteria are certainly interdependent, there seems to be quite a degree of freedom to choose among alternative techniques once the problem has been formulated. Throughout this paper an attempt will be made to relate the discussion of the appropriate techniques to the respective problems under investigation.

The first criterion leads to a distinction between macroeconomic and microeconomic models. Macroeconomic models have generally emphasized global issues like the impact of alternative policies on real income, rate of inflation or balance of payments. [17] Often they included problems of intersectoral factor allocation and the application of control policies to change the intersectoral or interregional resource allocation in a desired direction. [17]

On the other side there are studies which analyze the dynamic performance of an individual sector mainly within a microeconomic framework. Models of this kind [7,20] deal explicitly with the decision making process in the individual firms of the respective sector, appropriately aggregated to more or less homogenous groups on the district or regional level. Intersectoral relations (e.g., farm-nonfarm) are usually given as exogenous. [7] Public policy instruments as well as the sector's performance variables may be modeled in any detail and any degree of disaggregation and hence the models can be of immediate use in the real implementation of the individual policies. Recursive Programming models for sector analysis would be an example for this kind of approach. Single periodic programming models would be another one, but they may be excluded here, because they do not yield time paths of the performance variables. Between the mainly macro- and the mainly micro-oriented models there are various kinds of intermediate types, where both the relationships within and between agriculture and the rest of the economy play an important role. [19,9] A thorough classification and description was recently given by Thorbecke. [26]

The General Systems Simulation Approach, as being developed and applied by the simulation group at Michigan State University is an example of an attempt to combine the macroeconomic multi-sectoral and the microeconomic intrasectoral analysis. The system's model contains different components,

differing according to the geographical regions and the socio-economic problems involved.

The second criterion to distinguish between various types of approaches has to do with the techniques used for the analysis. By technique we may mean a method of analysis which either uses one unique algorithm, specialized to solve mathematically stated and particularly structured problems or—if the problem is not mathematically stated—which uses well defined and communicable rules to get quantified results for a particularly structured problem. Hence, the methods listed in the introduction may be called "techniques" in this context.

The system under consideration may be either analyzed by only one unique technique or by several different techniques. Examples of the first type (one technique approaches) are: (1) Models based on systems of simultaneous equations for which the values of the endogenous variables are simulated for consecutive periods after the coefficients have been estimated. This technique is described as policy simulation models by Naylor. [24] It is applied on the multisectoral macro-level, for instance, in the Brookings model. [10] (2) Models using single periodic linear programming with parametric changes of various coefficients. On the agricultural sector level there are applications by Duloy and Norton for Mexico [7] and by Bauersachs for Western Germany. [2] On the multisectoral macro-level an example would be the model by Bruno for Israel. [3] All these models provide "schedules of optimal solutions" for alternative assumptions about coefficients, factor availability or supply and demand conditions.

Examples for the multi-technique approaches are: (1) The General Systems Simulation model of the agricultural sector by Manetsch et. al., which

consists of several building blocks (agricultural production and marketing, interregional trade, nonagricultural economy, population, etc.) each of them being composed of interrelated functional relationships. Within each block there are recursively linked or independent components which are modeled by different techniques. (2) Recursive Programming models, as applied to both, developed [15,11] and developing countries [7,20] and particularly based on the work of Day [6]. These models generally consist of a single- or multi-periodic linear programming component (farm-firm decision component) and a feedback component, which by itself may be composed of several subcomponents (real production, marketing and trade, consumption, population, etc.) and modeled by different techniques. (3) "Open ended" models, as described by Thorbecke and applied to agricultural sector analysis of Guatemala [9] or Columbia. In the model for Guatemala, a macroeconometric model is set up out of six behavioral relationships which are estimated with ordinary least squares regressions and used for predictions. In addition to that, five identities are defined and multiplier impacts are computed from the reduced form of the whole model. This model then provides the consistency framework for various projections of agricultural consumption and production, accomplished by various techniques.

3. Multicomponent System and Multiple-Technique Approach

The essential distinction between the models using only one technique and those using several techniques goes back to the distinction between a generalized design, using a set of simultaneous equations to describe the structure of a system (firm, industry or economy) and the modular or building-block design with individual blocks within the whole system. [23] While the generalized design may be derived from the general Walrasian equilibrium concept, the

building-block design is based on the assumption that the whole system may be broken down into single equations or blocks of simultaneous equations, which are either completely independent (e.g., geographical regions without trade) or recursively linked (e.g., consumption decisions depending on income in previous periods). Thus, the precondition of the ability to handle various techniques within the whole model is the ability of the economic analyst to find those linkages and to define appropriate independent building blocks.

The difference between the two concepts may become clearer by comparing the Policy Simulation Approach by Naylor and the General Systems Approach of the Michigan State University team in mathematical notation:

The general form of a simulation model of an economic system can be written as:

$$y(t) = F[y(t-1), \ldots, y(t-p), x(t), z(t), u(t)]$$

with $y(t)$ = vector of endogenous variables

$x(t)$ = vector of exogenous variables

$z(t)$ = vector of policy variables

$u(t)$ = vector of random disturbance variables

p = maximal length of lag in the endogenous variables

This model put into the linear form of the Naylor approach [24] becomes:

$$Ax(t) + By(t) + \sum_{j=1}^{p} B_j y(t-j) + Cz(t) + D = u(t)$$

or in the reduced form:

$$y(t) = -B^{-1}Ax(t) - B^{-1} \sum_{j=1}^{p} B_j y(t-j) - B^{-1}C\,(t) - B^{-1}D + B^{-1}u(t)$$

with A, B, B_j, C, D = coefficient matrices whose parameters have been estimated by standard econometric techniques

In the General Systems Approach it is assumed that the constraint structure of the whole system has not necessarily to be fully interdependent and hence that the vector y of endogenous variables may be split into n subvectors $y_i(t)$, $i = 1,2, \ldots, n$.

$$y(t) = \begin{bmatrix} y_1(t) \\ \cdot \\ \cdot \\ \cdot \\ y_n(t) \end{bmatrix}$$

Since interactions exist only in the lagged terms and in the exogenous and policy variables, it is possible to use different sets of functions F_i to model each subset of variables (building blocks):

$$y_1(t) = F_1[y(t-1), \ldots, y(t-p), x(t), z(t), u_1(t)]$$

$$\vdots \qquad\qquad \vdots$$

$$y_n(t) = F_n[y(t-1), \ldots, y(t-p), x(t), z(t), u_n(t)]$$

Hence, it is also possible to use different techniques to solve these building blocks for the endogenous variables. Likewise, it becomes possible to quantify the coefficients of each block by different techniques. If each subvector $y_i(t)$ does only contain one element, then the system would be completely recursive and consist of n individual equations. If this cannot be assumed, i.e., if some of the blocks consist of a set of simultaneous equations, then the system would be block recursive. In the Michigan State model, the nonagricultural production sectors are represented by a set of simultaneous equations, while the other components are composed of single equations. Hence, the system is block recursive.

The following example demonstrates how a system of two building blocks could be modeled, where one block contains a maximizing model with an explicitly stated objective function. Let, for example, $n = 2$. Assume that $y_1(t)$ represents a subvector of endogenous variables within a macroeconomic subsystem which can be solved by a set of linear simultaneous equations like the Naylor approach. And let $y_2(t)$ represent the solution vector of a microeconomic subsystem (e.g., farm-production sector) which can be the solution to a linear programming model. Then the system's model can be written in the following form:

$$y_1(t) = -B_1^{-1}A_1x(t) - B_1^{-1}\sum_{j=1}^{p} B_{j1}y(t-j) - B_1^{-1}D_1 + B_1^{-1}u_1(t)$$

$$\text{and } y_2(t) = \{y_2^*(t) \mid \max_{y_2(t)} \langle \alpha(t), y_2(t) \rangle\}$$

$$\text{s.t. } A_2(t)y_2(t) \le b_2(t) = b_2(t)[y(t-1), \ldots, y(t-p), z(t), u_2(t)]$$

$$y_2(t) \ge 0$$

with A_1, B_1, B_{j1}, C_1, D_1 = coefficient matrices of the subsystem 1

$\alpha(t)$ = vector of objective function coefficients in subsystem 2

$A_2(t)$ = coefficient matrix in subsystem 2

$b_2(t)$ = constraint vector in subsystem 2

$u_1(t)$ = vector of disturbance variables in subsystem 1

$u_2(t)$ = vector of disturbance variables in the feedback equations of subsystem 2

* to indicate optimality

In this example, the subsystem 2 has the form of a recursive linear programming model. The example shows how a linear programming model can be linked to the other building blocks of a system's model. It also shows how the General System Approach can include a linear programming component.

Hence, one can define Recursive Programming as a particular case of the General Systems Approach. Certainly, a variety of other techniques could be incorporated, given the modular design of the system's model is appropriate.

Which techniques the system should include depends on the objectives of the particular projects. It also depends on the way the system's model can be broken down into separate components and what the properties of these components are. Finally, it depends on the computational problems and the costs which would be involved. The following chapters are an attempt to discuss these problems in a very general way. Detailed considerations can only be made if a particular real problem has to be analyzed.

4. The Agricultural Sector, a Multicomponent System

Before details and design principles can be discussed, a brief summary of the objectives of agricultural sector analysis will be given. Generally, the performance of the following variables is investigated: (1) farm income (including distribution); (2) production (by products, regions, farm groups); (3) level of nutrition; (4) employment in agriculture and non-agriculture, migration; (5) input requirements, investment and disinvestment; and (6) degree of food self-sufficiency.

A variety of policy instruments is tested alternatively or in a certain combination to determine their effect on performance variables. The following is a more or less arbitrary selection of groups of those instruments: (1) price and market policies; (2) stimulation of private investment or public investment within the farms, in non-agricultural input or processing industries; (3) production research and extension; (4) non-agricultural employment generation and stimulation of labor mobility; (5) public investments to improve the "quality of rural life" [18], of education, etc.

Given this general framework of agricultural sector analysis, a model of this sector has to be set up, which gives insights into the sector's behavior and particularly the reactions of the performance variables to the various policies. Main components have to be identified and linkages between them have to be analyzed. From these objectives it follows that some of the problems to be investigated, like the adoption of new products or technologies and the investment or disinvestment in equipment on the farms, should be modeled on the micro-level, whereas others, like the job generation in non-agricultural sectors, foreign exchange policies, etc., may be modeled on the macro-level. However, particular studies may deviate from these rules.

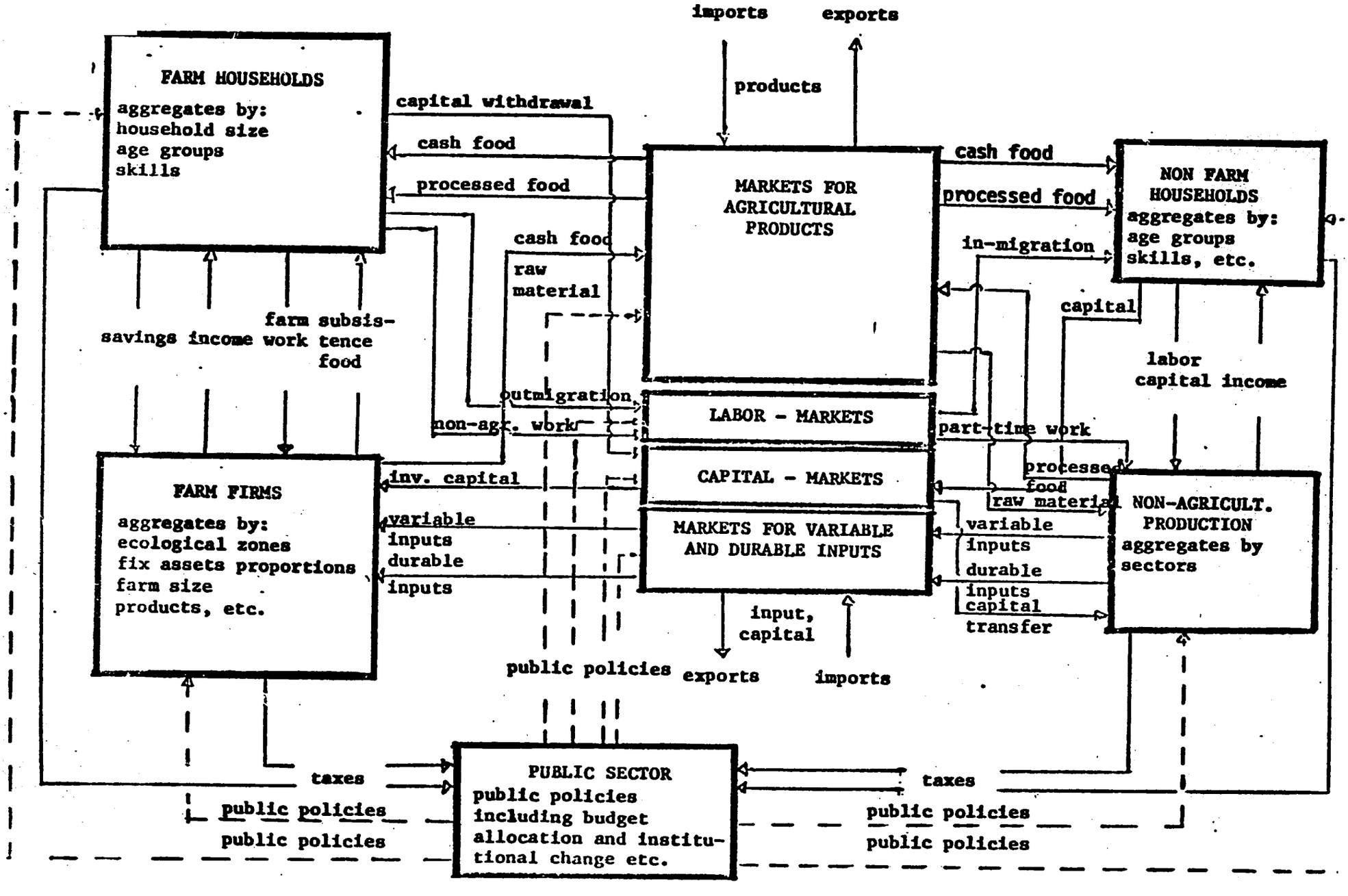
As a basis for the discussion of design principles, of component linkages and of techniques, the following main components or building blocks of an agricultural sector model may be defined:

1. the farm-firm component
2. the household and population component (agricultural and non-agricultural)
3. the non-agricultural production component
4. marketing and trade
5. the public sector.

The main inputs and outputs of the various blocks are shown schematically in the diagram of Figure 1.

The basic components of this system are the farm-firms and farm-households. The reactions to public policies result from individual decisions in these units. The model should include the constraints, the objectives and rules on which those decisions are based. Appropriate aggregates by regions, farm size and household size have to be defined. A linkage mechanism between firms and households will be discussed later.

FIGURE 1: SCHEMATIC REPRESENTATION OF MAIN COMPONENTS OF AN AGRICULTURAL SECTOR MODEL



Product and input markets are further components. A separation from the production component becomes possible by the assumption of a lagged response of farmers' production and investment decisions to prices and market conditions. Once the production decisions are made, random disturbances from weather, soil, etc., have been in effect, and subsistence consumption has been determined, the market supply is fairly inelastic with respect to price changes. Hence, a recursive linkage between product markets and farm-firm allocation components seems reasonable. Similar considerations may hold for some input markets, especially the labor market where various kinds of adjustment lags can be observed. In the markets for variable inputs farmers do often times base their decisions on actual prices, hence demand and supply conditions should be considered simultaneously. In many developing countries, however, there is a considerable public influence on these markets and prices may be fixed by the policy maker.

A non-agricultural production component is introduced to keep track of supply conditions for industrial inputs used in agriculture as well as of the employment effects of non-agricultural investments for migrants from agriculture. A regional disaggregation as well as the distinction of special skill requirements of the jobs may be necessary. Outputs of this component are input supply and labor and capital demand functions which provide the linkage to other components. Migration, usually a lagged response to agricultural non-agricultural income differentials, job opportunities, etc., provides the recursive linkage between the agricultural and non-agricultural household components.

1/ The design principles for intermediate enterprises like the so-called "agribusiness depend on the particular objectives of the study. Here they will be subsumed under the non-agricultural sector.

Finally, a public sector may be modeled as a separate component. Since it is agreed that a social welfare function cannot be quantified or even be observed and that a decision rule on the sector level can hardly be defined, this component will not include the evaluation of alternative system's performances. In fact, it is the declared intention of most of the studies to provide the decision maker with a variety of possible strategies and performances to avoid any kind of prescription and to leave the final decision on which strategy should be chosen to the decision maker. Hence, this component usually represents just an exogenously determined budget allocation. But it may also include a policy control subcomponent which causes adjustment of the recent policy strategy, if certain performance variables pass given upper or lower bounds.

Before specific considerations will be made on the appropriate techniques which a General Systems Approach might be able to handle, some final conclusions shall be drawn from the discussion so far. In all the previously mentioned components decisions are made by individuals or groups of individuals. From component to component, these individuals may have very different objectives, different values for goods and bads, different decision problems and different levels of knowledge about their environment as well as their own decision unit. Given this diversity, it seems reasonable that the behavior of the system with respect to alternative government policies cannot be described by one unique technique, i.e., the "General Systems Approach" is an appropriate concept. It enables the model builder to incorporate explicitly different decision rules and behavioral patterns for some components or to work on a high aggregate level for others.

5. Potential Techniques to Model the Various Components

The following section contains some thoughts about appropriate techniques for particular components. Emphasis will be laid on the farm-firm and the non-agricultural production components. This selection results not only from space limitations, but also from the consideration that both "closed multitechnique approaches" previously mentioned, i.e., the Systems Simulation Approach as applied by the MSU team, and the Recursive Programming Approach, could mutually gain from an adoption of these components. The Systems Simulation Approach might need improvements in the techniques to model the farm production component. The Recursive Programming Model might probably be expanded by a macro-master model of the rest of the economy.

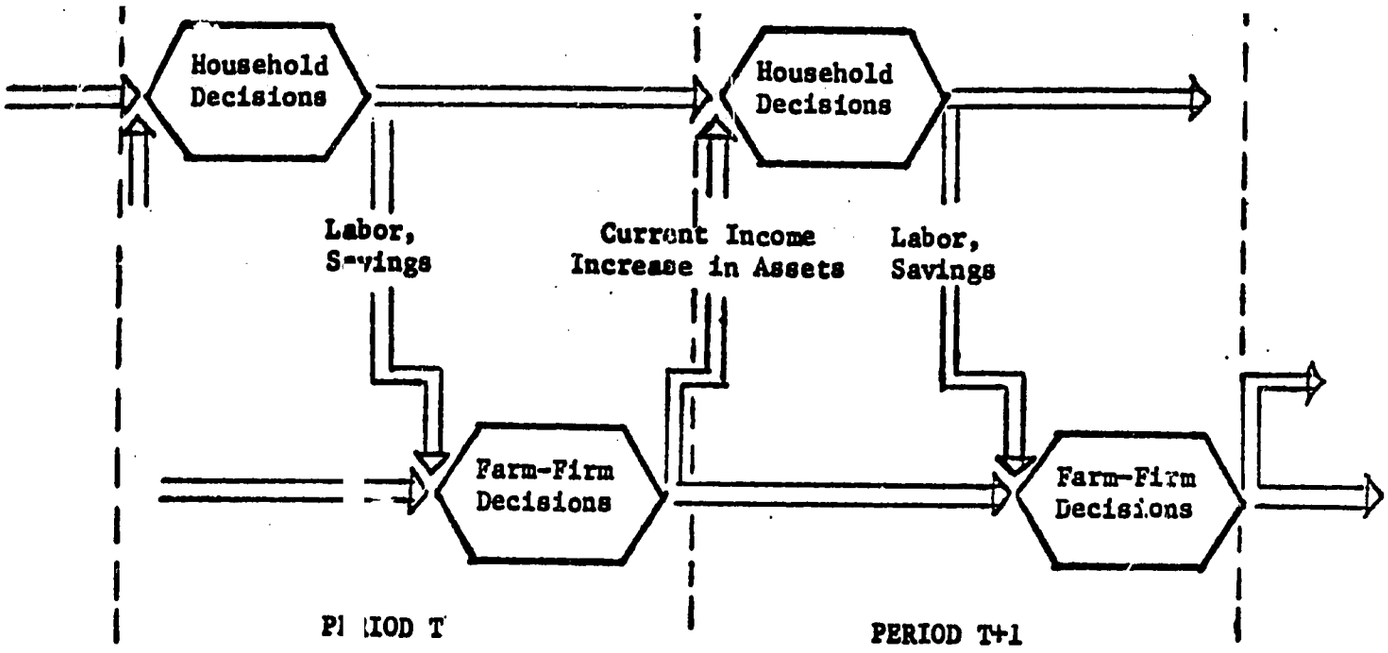
5.1 The Farm-Firm Component

Decisions concerning production and investment in agriculture are typically made by the same decision unit which decides over the distribution of cash incomes in consumption and savings and the allocation of labor capacity in leisure and work. Certainly, both household and firm decisions are interdependent, but since the simultaneous determination of these decisions would require a quantified time preference function, most models are based on a decomposition of farm-firm and farm-household decisions, as shown in the diagram of Figure 2 [14].

According to these assumptions, household decisions can be related to income in previous years, household size and total assets. Hence, the farm-firm decisions can be modeled separately from the household decisions.

What are the design principles of this component? They should generally reflect the following [7,14]: (1) The multiproduct and multiprocess

FIGURE 2: Recursive Linkage Between Firm and Household Decisions



character of agricultural production, with a variety of resources being commonly required by several processes; (2) The goal structure and the decision rules effective in the farms; (3) Technological change; (4) Asset fixity; (5) uncertainty; (6) Adoption and diffusion processes for new technologies.

As previously indicated, the multicomponent approach is flexible to include various kinds of techniques. Following are some thoughts about the more frequently applied techniques: (1) regression analysis; (2) various managerial planning techniques; and (3) mathematical programming.

(1) Regression analysis is a commonly used technique to estimate yield and supply response to changes in prices and price-ratios of various lags. Effects of technological or institutional changes, etc., are introduced by "shifter variables." The supply of interdependent products may be estimated simultaneously. There are several reasons why regression analysis appears to be

inappropriate for the purposes of this investigation: First of all, the analysis depends on time series data, which are often not available for a sufficient period. Also, historical data usually do not include drastic changes in technologies or socio-economic policies, which may be expected for the future. Hence, the shifter variables will not account for these changes [12]. The problem of asset fixity and irreversible supply response is not handled properly, although some improvements have been suggested recently [28]. Finally, this technique does not account for the interdependence between production and investment decisions which are an essential characteristic of the farm-firm activities.

(2) A variety of more or less formalized techniques, which are frequently applied to management decision problems could be considered. Budgeting and various computer search methods are examples [13,4]. They lead to the investigation of a limited number of system's solutions consistent with the physical, financial and behavioral constraints. The selection process is guided by some problem oriented decision rules, which may not lead directly to the maximum of the underlying objective function, but come close to it.

While the use of budgeting in particular decision problems on individual farms does not require a formal searching rule and usually involves the whole creativity of the manager, a computerized simulation requires mathematically stated rules. Trend extrapolations of past developments might be the simplest procedure, a ranking of alternatives according to particular factor productivities may be another one.

The latter comes close to the technique which was apparently used in the MSU-Nigerian model. A most limiting factor is determined a priori.

It is then assumed that farmers try to maximize their profit expectations and that they allocate their production alternatives according to the profitability with respect to this predetermined factor. Consistency checks are made for various other limitations and the available resources are utilized according to a profitability ranking order. Adjustments of the present organization due to changes in the expected profitability differentials only take place in a lagged response, the various simulated lags standing for behavioral constraints, diffusion effects, etc.

The strength of these techniques lies in their ability to incorporate easily various nonlinearities, especially in the objective function. However, for the purpose of agricultural sector analysis, which deals with many small enterprises, whose decisions are generally based on the assumption of completely elastic demand and supply functions, this may often not be very relevant.

On the other hand, some weaknesses of the aforementioned technique should be discussed. The first is the limitation of the profitability consideration to one scarce factor. This implies that farmers assume the marginal value product of other factors to be zero. Although this may be true for very short time increments, this is usually not the case for time periods of one-half or one year. Relationships between activities which may be recursive on a one-month basis do often become interdependent when one year is considered to be the time increment. Land capacities, labor in critical seasons, investment capital, the sizes of animal cohorts, or behavioral constraints are explicitly or intuitively considered simultaneously by the decision maker. Even if in an initial period one single production factor can be identified as being scarce,

it is not necessarily true over time. Hence, an initially correct assumption may become wrong later during the projected time horizon.

(3) Mathematical programming appears to be a suitable technique to represent farmers' decision making process as a rational choice among alternative production, investment and disinvestment activities, even if limited information and cautiousness towards new technologies is assumed. Examples including dynamic linkages between periods exist from both developing and developed countries [7,20,11]. Aggregates of farm types or ecological zones can be identified as individual blocks within a block-diagonal matrix with overlapping equations for regional or national constraints. Hence, intrasectoral distribution problems can be investigated explicitly, as well as farm growth processes for the various aggregates. Mathematical programming is capable of accounting for the multiproduct-multiprocess character of the farm firm. Multiple goal structures can be incorporated by a lexicographic objective function [7]. Learning and diffusion processes can be introduced by appropriate constraints and dynamic linkages to previous decisions (flexibility constraints). Finally, long term effects of investments and perennials could be considered in a multiperiodic matrix, if the empirical evidence indicates such behavior on the farms. Parameters for periods later than the presently projected period would then be repeatedly revised as new informations are collected by the farmer (Rolling Plan Models [21]).

Another advantage of activity analysis is the interpretation of the results in terms of the dual solutions, i.e., the endogenously determined opportunity costs for the constraints and the marginal loss values for marginal changes in the activity levels. The dual solution allows a

systematic evaluation of the stability and the influence of the various physical, financial and behavioral constraints on the performance of production and allocation. It may lead to hypotheses about the incentives underlying changes in the behavior of the farm-firm component over time [16].

5.2 The Non-agricultural Production Component

The MSU-Nigerian study includes an attempt to incorporate the main agricultural non-agricultural linkages in the model for sector analysis. It does this by means of a national input-output table. It enables an analysis of the effects of agricultural development on the national economy and also of changes in the non-agricultural economy on the agricultural sector. Final demand for consumption, investment and exports for the main non-agricultural sectors are either determined endogenously with regression models or (in the case of exports) given exogenously. The respective figures from the agricultural sector are provided by the previously mentioned simulation runs of the detailed agricultural model. Assuming linear aggregated production functions, this final demand is then converted into the intersectoral flows of goods and services and into import and labor requirements. Employment is computed for different labor categories and real wage rates are calculated for each of them. The latter are then the basis for the projection of intersectoral migration. The process is repeated for the following period after the input-output coefficients have been adjusted to account for technical changes or shifts in the technology mix. A detailed description of the component is given by Byerlee [5].

The strength of this procedure is the consideration of the intersectoral interactions in a consistent framework. However, problems which still have to

be investigated, are related to the application of the input-output table for predictions, the incorporation of technical change or shifts in the sectoral input mix. If these problems can be solved, then this technique could provide the linkage to various kinds of micro-models including a recursive programming model, whose results are appropriately aggregated.

5.3 Other Components

From the discussion so far, the incorporation of any kind of technique for each of the components appears feasible, if a computerization is possible. This paper is not the place to discuss all of them in any detail. The recursive linkage mechanism enables the model builder to choose varying levels of aggregation and accuracy for the components.

The population components which is emphasized especially in developing countries, may include various techniques to account for population dynamics, distributions within cohorts and distributed lags in the shifts between them. Similar models may be used to simulate the life cycle of perennials, as described by Abkin [1].

The techniques to model the marketing and trade components vary from analytical methods like quadratic programming, if price elastic demand functions are included, or linear approximations as developed by Takayama and Judge [25], to iterative techniques, as they were originally suggested by Tramel and Seale as "reactive programming" [27], both yielding equilibrium prices and transshipment patterns.

If the evaluation of alternative public investment programs is required, then a computerized Cost-Benefit Analysis can be implemented which leads to a selection of a particular well defined program. This program then becomes part of the policy strategy for which the whole simulation run is accomplished.

If predefined public investment programs are less important than timing of individual tasks within the execution of that program, then Programming Evaluation and Review Techniques (PERT) may also be incorporated. However, it seems doubtful whether the incorporation of these detailed project evaluation procedures in the comprehensive sector analysis is really necessary and useful. On the one hand it is the intention of the whole approach to provide the decision maker with broad information about the prospective impacts of alternative programs and policies. Hence, one should not exclude some of them according to problematic cost-benefit considerations. On the other hand, the timing may be better investigated in the implementation phase of the program, especially because the time increments of the whole sector model would usually not be those necessary for the PERT technique.

6. Computational Implications in including various techniques

Some brief remarks will be made on possible computational problems which might occur with the incorporation of particular techniques. These may be caused by a discrepancy in core capacity and core requirements or by unsatisfactory high computation times.

The character of the multicomponent system's model with recursively linked or independent components should usually help to avoid problems with the core capacity. If a large individual component with simultaneous equations is included, a problem may arise to keep the whole main program including other subroutines in the core simultaneously. This is particularly true for linear programming. A sequential shifting or even a linkage of two computers would then be the only solution.

Another disadvantage which is often mentioned in connection with linear programming is the long computation time. This is so important, because insufficient knowledge about parameters and functional relationships may lead

to the necessity of applying Monte Carlo techniques and various sensitivity tests. But since the approach, which is discussed here, would be recursive programming, it should be mentioned that the computation time is generally decreasing very drastically when the linear programming component is run recursively. This is possible because once an initial solution is obtained, it is possible to start the following problems with the basis of the preceding problem rather than with a zero basis. This time saving effect occurs particularly when only relatively small changes in the production and allocation pattern are permitted from one period to another in order to account for uncertainty, cautiousness and learning.

More recently, a very efficient recursive programming processor for matrices of up to 100 equations has been developed in Wisconsin [22], which could ease the combination of a system's simulation model with recursive linear programming.

Finally, the appropriateness of a technique does not only depend on the computation time and the costs, but also on the explanatory and predictive power of the technique and the benefits which the decision maker could probably gain.

7. Summary

The discussion in this paper may be summarized as follows: The General Systems Analysis Approach as applied by the MSU team is flexible in the incorporation of various techniques and does not necessarily depend on any particular one. The flexibility is possible, because the system under consideration is broken into recursively linked building blocks.

This multicomponent approach modeled with several techniques is also applied in Recursive Programming Models and other "open ended" models. Since Recursive Programming Models can be considered as a particular case of a General Systems Approach, one may even say that the flexibility with respect to

the handling of various techniques is higher for the General Systems Approach than for Recursive Programming.

However, these considerations would remain an academic game if they were not extended by an evaluation of this flexibility and a discussion of the economic questions which the models are supposed to answer. Given the complexity of the agricultural sector and the interactions with the rest of the economy and given the diversity in the goals and decision rules, a multicomponent approach appears to be appropriate and problem oriented, especially since some recursive linkages seem to exist in reality. The multiple-technique approach enables the model builder to consider different objectives, tastes and preferences as well as different decision rules, which may exist for the varying groups of individuals within the society. Hence, he can avoid the necessity to find a common denominator of values for all the members of the society.

An analysis of the only empirical study which exists so far (the General Systems Approach of the MSU team) leads to some criticism with respect to the techniques used to model the farm-allocation and investment decisions. The interdependency between various production and investment activities is not sufficiently considered.

A recursive linear programming model might have greater capability to represent farmers behavior. It may also contain more direct and explicit informations about the specific problems of policy implementation (types of investment goods, capacities, etc.). An incorporation into the General Systems Approach might be considered.

Finally, the building block design, used in the General Systems Approach with the compnents being processed successively, enables the model builder to add further micro- and macro-components and to model them with various techniques without serious computational difficulties.

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