A SYSTEMS APPROACH TO AGRICULTURAL SECTOR DEVELOPMENT DECISION-MAKING: BUILDING AND INSTITUTIONALIZING AN INVESTIGATIVE CAPACITY

George E. Rossmiller, Editor

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PREFACE

In recent years interest in using computerized models as an aid to planning and policy analysis has been increasing; government officials in many countries are searching for better means of assuring analytic input to their decisions. However, many are reluctant to make the sizable investment required for sophisticated computer-based modeling efforts, partly because the techniques and methodologies are generally not well understood by decision-makers, often do not include all the information necessary to a comprehensive analysis, and sometimes lead to unworkable prescriptions for action.

In the mid-1960s Michigan State University joined with five other U.S. institutions to form The Consortium for the Study of Nigerian Rural Development. The study was sponsored by the U.S. Agency for International Development, and its purpose was to evaluate this agency's projects promoting Nigerian rural development. This led to the need for a sector analysis. A traditional, noncomputerized methodology was used which relied heavily on paper, pencils, and desk calculators for the quantitative analysis. When the study was approximately two-thirds complete, some of the team members became interested in the possibility of using a systems approach and a variety of simulation techniques that had been developed in electrical engineering and systems science and that were just beginning to be adapted to problems in social science. However, it was determined that this approach and these techniques were not then developed enough to be of use in a highly applied and operational project, such as that undertaken by the consortium.

Interest in adapting the system approach and simulation techniques to agricultural sector development planning continued at Michigan State University, and in 1969 a contract (AID/csd-1557) with the U.S. Agency for International Development was negotiated to explore the possibilities. Work conducted under this contract was used extensively in developing the Nigerian perspective agricultural plan, and it was clear that a general system simulation approach to agricultural sector development analysis was feasible and that its potential was great.

On the basis of this conclusion, a second contract (AID/csd-2975) was negotiated between Michigan State University and the U.S. Agency for International Development that called for further development of the approach and the models; it also called for their institutionalization and use within the agricultural decision structure of one or more countries. In 1971 the MSU Agricultural Sector Analysis and Simulation Projects team began collaboration with the Republic of Korea's National Agricultural Economics Research Institute, an agency of the Ministry of Agriculture and Fisheries. The purpose of this collaboration was to develop an investigative capacity for collection and organization of data that would enable analysis and synthesis of agricultural development problems related to planning; policy formation; program development; and project design, implementation, and evaluation in the Republic of Korea.

The purpose of this volume is to explain the general system simulation approach as a viable basis for providing input to planning and policy decision-making in agricultural sector development. This is done through discussion of the philosophic orientation of the approach, its eclecticism with respect to modeling techniques and types and sources of data, its relationship to the decision-making process, and the establishment of its credibility with decision-makers. Also discussed are the prerequisites for institutionalization and utilization of the general system simulation approach to agricultural sector development planning and policy analysis within the agricultural decision structure of a national government. The development and institutionalization of the approach in Korea is detailed, and conclusions are drawn about transferability and preconditions for utilization in other developing (or developed) countries.

A wide and varied audience for this volume is anticipated. It should be of particular interest to

1. Agricultural sector development decision-makers at the national level interested in improving the quality of their planning policy formulation, program development, and project design, implementation, and evaluation
2. Agricultural sector development staff and policy analysts searching for more useful and comprehensive approaches to problem-solving analysis
3. Students of the systems approach interested in methodology and application of systems analysis to socio-economic problem areas

4. Students of economic development within and outside the academic community who are interested in alternative methodological approaches to agricultural sector development problem-solving

In writing for such a diverse audience, we run the risk of probing too deeply in some areas and not deeply enough in others to satisfy any given reader. For those of you who are quantitatively oriented and are interested in a more in-depth mathematical treatment of the models, we can only refer you to other documentation by the project team. We urge those who find some of the concepts and the small amount of mathematics used laborious to skip over those sections or equations. In doing so, most will find the general meaning still apparent.

The first five chapters provide a detailed discussion of the general system simulation approach as part of the decision process and describe the requirements for institutionalization and utilization of the approach in the agricultural sector development decision-making structure. The next ten chapters (6-15) discuss the institutionalization of the general system simulation approach within the Ministry of Agriculture and Fisheries, Republic of Korea; offer a component-by-component description of the Korean agricultural sector model; and give illustrations of its application for planning and policy analysis purposes. The next two chapters (16 and 17) discuss the development of two subsector models related to the agricultural sector modeling effort--a grain management program model for use as an on-line management tool for government grain price, stock, storage, and trade management decisions; and a static annual grain price policy analyzer for use in analyzing consequences of grain-pricing decisions on production, consumption, inflation, foreign exchange, and government grain management accounts. The last chapter discusses lessons learned with respect to transferability of the approach to other countries, subject-matter areas, and problems.

It is impossible to individually acknowledge the contributions by the many people and institutions who have been a part of the projects upon which this book is based. To them, however, the contributors to this book owe a heartfelt debt of gratitude. We specifically single out for special acknowledgment and appreciation the institutions with which the contributors to this book are affiliated for providing us the opportunity to participate, the Government of the Republic of Korea for its contributions and cooperation, and the U.S. Agency for International Development for the funding which made both the projects and the book possible. Finally, a special thanks to Bert M. Pulaski, project administrative officer, who released us from untold logistic and administrative details and kept us solvent, and to our secretarial staff--Edith Nosow, Kyong Soo Kim, and Judy (Pardee) Duncan for a difficult job well done.

George E. Rossmiller,
Editor for the Team

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LIST OF CONTRIBUTORS

ABKIN, Michael H.	Department of Electrical Engineering and Systems Science Michigan State University East Lansing, Michigan
BAUERSACHS, Friedrich	Institut für Agrarpolitik, Marktforschung und Wirtschaftssoziologie Universität Bonn Bonn, Federal Republic of Germany
CARROLL, Tom W.	Computer Institute for Social Science Research Michigan State University East Lansing, Michigan
DE HAEN, Hartwig	Institut für Agrarökonomie Universität Göttingen Göttingen, Federal Republic of Germany
DUVICK, Richard D.	Department of Agricultural Economics Ohio State University Columbus, Ohio
GIBSON, Forrest J.	Department of Electrical Engineering and Systems Science Michigan State University East Lansing, Michigan
JOHNSON, Glenn L.	Department of Agricultural Economics Michigan State University East Lansing, Michigan
JONES, Francis C.	Food and Agriculture Officer U.S. Agency for International Development (Retired) Washington, D.C.
KIM, Dong Min	National Agricultural Economics Research Institute Ministry of Agriculture and Fisheries Seoul, Korea

LEE, Jeung Han	Department of Agricultural Management Gyeong-Sang National University Jinju, Gyeong-Nam, Korea
MANETSCH, Thomas J.	Department of Electrical Engineering and Systems Science Michigan State University East Lansing, Michigan
MANGUM, Fred A., Jr.	Department of Economics and Business North Carolina State University Raleigh, North Carolina
ROSSMILLER, George E.	Department of Agricultural Economics Michigan State University East Lansing, Michigan
SLOBODA, John E.	Center for Japanese Studies University of Michigan Ann Arbor, Michigan
TEIGEN, Lloyd L.	Economic Research Service U.S. Department of Agriculture Washington, D.C.
THODEY, Alan R.	Department of Agricultural Economics California State University Fresno, California

PART ONE

A GENERAL SYSTEM SIMULATION APPROACH

CHAPTER 1

IMPROVING AGRICULTURAL DECISION-MAKING: A CONCEPTUAL FRAMEWORK

Glenn L. Johnson
George E. Rossmiller

Introduction

Planning and policy decision-making are recognized as necessary and legitimate activities of governments throughout the world [28]. As socio-economic linkages and interdependencies become more complex within and between nations, planning and policy determinations become increasingly important functions of national governments. With the limited resources available to raise the level of the human condition, concern for enlightened decision-making by governments in carrying out these functions is imperative.

Recently agricultural decision-makers and development analysts, in their search for new and better means of agricultural development, have turned toward a more comprehensive and systematic view, which has become known as the sector analysis approach. This has been due to dissatisfaction with other, more limited analytical approaches and the increasing recognition that agricultural sector development is comprised of literally thousands of separate, but interrelated, problems. For example, in many developing agricultural economies, population and rising incomes are pressing against the capacity of limited agricultural resources and traditional agricultural production techniques to increase and adapt food production to demands. Food prices are high, while farm incomes are low. Scarce foreign exchange is often used for increasing importation of food commodities. Diets lack sufficient protein, particularly animal protein. Labor is moving out of agriculture through farm-to-nonfarm migration. Agricultural credit is in short supply. Marketing systems, transportation, and communication networks are inadequate to serve a commercializing agriculture and an urbanizing economy. Inequitable ownership of productive resources and, hence, inequitable income distributions, are found within agriculture, within the nonagricultural sectors, between sectors, and among regions [48, 49]. Administrative and institutional constraints in the agricultural establishment limit the capacity of government to deal effectively with the problems of agricultural sector development [2]. The list could continue almost without limit, but it is already sufficiently long to illustrate the point that the problems are complex and interrelated and that solutions are certain to cause both desirable and undesirable consequences.

In solving agricultural sector development problems, therefore, a broad systems perspective and a generalized analysis are required. The necessary resources must be made available, the necessary institutional frameworks developed, and the necessary coordination provided to ensure improved decision-making and successful results. The basis and approach for improving in decision-making discussed in this book is in the context of agricultural sector development planning and policy formulation [31, 48, 49]. But it is completely generalizable to other sectors of the economy and other aspects of the socio-economic system.

Role of the Decision-Maker

The role of the public sector decision-maker is to develop consistent sets of plans, policies, programs, and projects to achieve a consistent set of goals based upon national value orientations [48, 49]. A broad objective of governmental decision-making is to solve immediate problems; to avert contemplated future problems; and to confront issues, which if left unattended, may become problems. The decision-maker then is primarily a problem-solver.

Planning activities in various countries ranges from the elementary and ad hoc to the extremely detailed and carefully conceptualized. The major objective of planning is to allocate public sector funds among governmental ministries and within ministries to policies, programs, and projects designed to meet the specified goals. In a mixed economy public decision-makers must give attention to the impact of public decisions on the actions of private decision-makers. In any planning process, assumptions must be made about changes and trends in the environment which will affect the activity and behavior of the system being planned. In addition, assumptions and theoretical concepts are applied to the system itself in projecting the consequences on the system and its outputs from alternative plan strategies. Policies are developed and implemented and planning strategies adjusted over time to affect system performance in desirable ways as both the system and its environment change.

The more the planner and policy decision-maker knows about the system and its environment and the way the system will respond to both external and internal stimuli, the better he can do his job. In recent years a mechanism adopted by many developing countries to formalize the governmental role in planning for economic development has been the four- or five-year economic development plan. In most cases a central planning agency is established, either as a super ministry or as a direct arm of the executive, with authority to establish development goals and guidelines and to coordinate the planning activities of the individual functional ministries toward meeting the established goals. The development plan approach implies the promise of a highly integrated and coordinated planning activity in which national values are well established and understood, realistic targets are clearly specified, budgets are allocated commensurate with the prescribed goals, and policies, programs, and projects are developed and implemented in a timely and consistent manner to fulfill the plan. Unfortunately, only in extremely rare instances does reality measure up to promise.

One of the dilemmas of the public sector decision-maker in most countries is the paucity of reliable data, information, and analysis at his disposal for decision-making. In many countries the decision-making role is vested in personnel who are rotated frequently among administrative posts. Often the civil servant staffs are neither well trained nor highly motivated. Thus, little in the way of a body of experience is built from which to draw an historical perspective in carrying out the decision-making role. Unless this body of past experience is organized in a useful way, it is difficult for decision-makers and their staffs to draw conclusions about the present state of affairs and to project the consequences of alternative courses of action into the future. This leads to a situation in which a great deal of ad hoc decision-making is done within a very narrow time perspective. The decision-maker often finds his time and energy consumed by the need to handle unanticipated problems and the consequences of ill-conceived decisions based on incomplete information and inadequate analysis. This situation is depicted in Figure 1, which shows a very narrow time perspective by the decision-maker and a very high level of short-term crisis activity. The decision-maker in this case has little experience and historical perspective, on the one hand, and little sense of the intermediate and long-range future, on the other.

Through more formal organization of historical experience into an easily accessible data and information system and the development of more formal analytical frameworks which can use that information and data in learning more about *future expectations* and *projecting the consequences* of alternative planning strategies, policies, and programs of action, a better time orientation of decision-maker activities can be attained, as shown in Figure 2 [18, 19, 30, 35, 37, 41, 52, 53]. This is one with a longer time perspective in both the past and the future, as well as a lower profile of activity concerned with the immediate present. A major portion of the rest of this book is devoted to discussion of how the Figure 2-type time orientation can be accomplished and why it is important to do so. Most countries have at least the rudimentary resources, human skills, and organizational abilities to improve public-sector decision-making for agricultural sector development.

A National Agricultural Decision-Making Capacity

The total capacity of a country for solving agrarian problems can be indicated by the large circle in Figure 3. In turn, that capacity

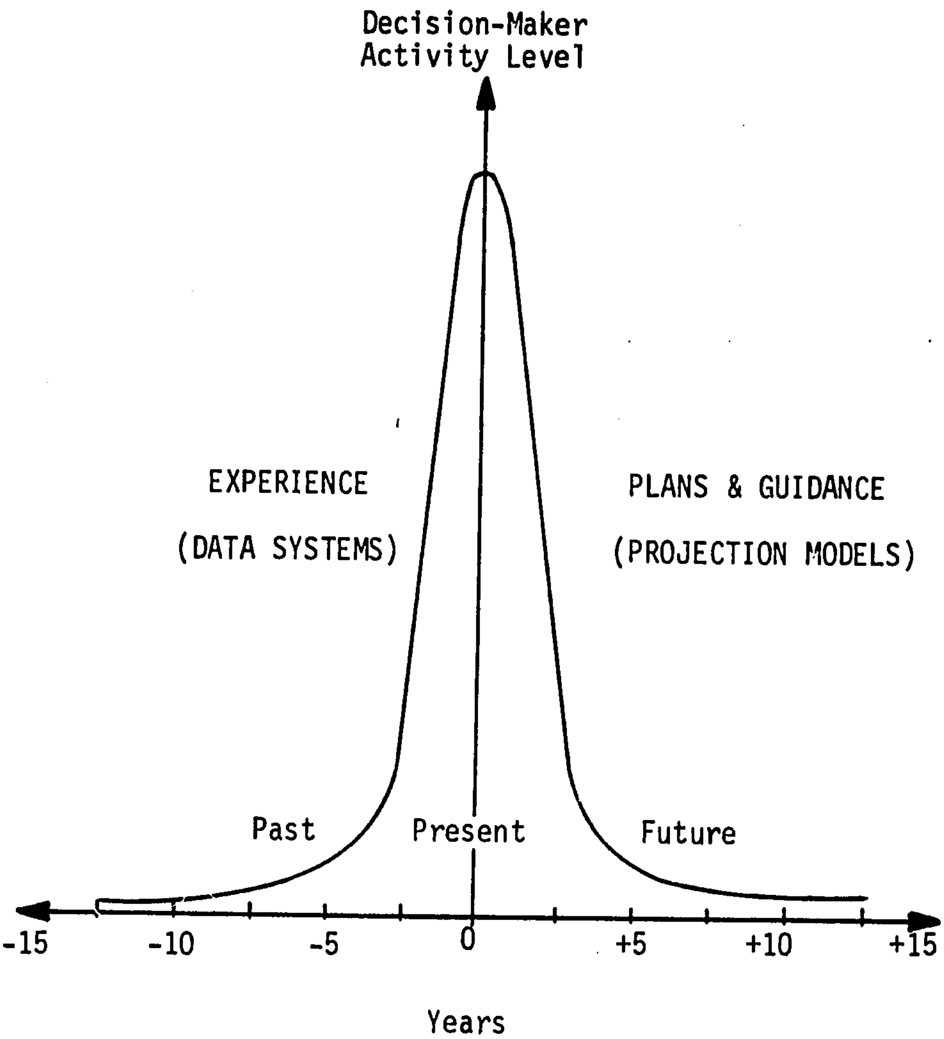

Figure 1. Common Time Orientation of Decision-Maker Activities

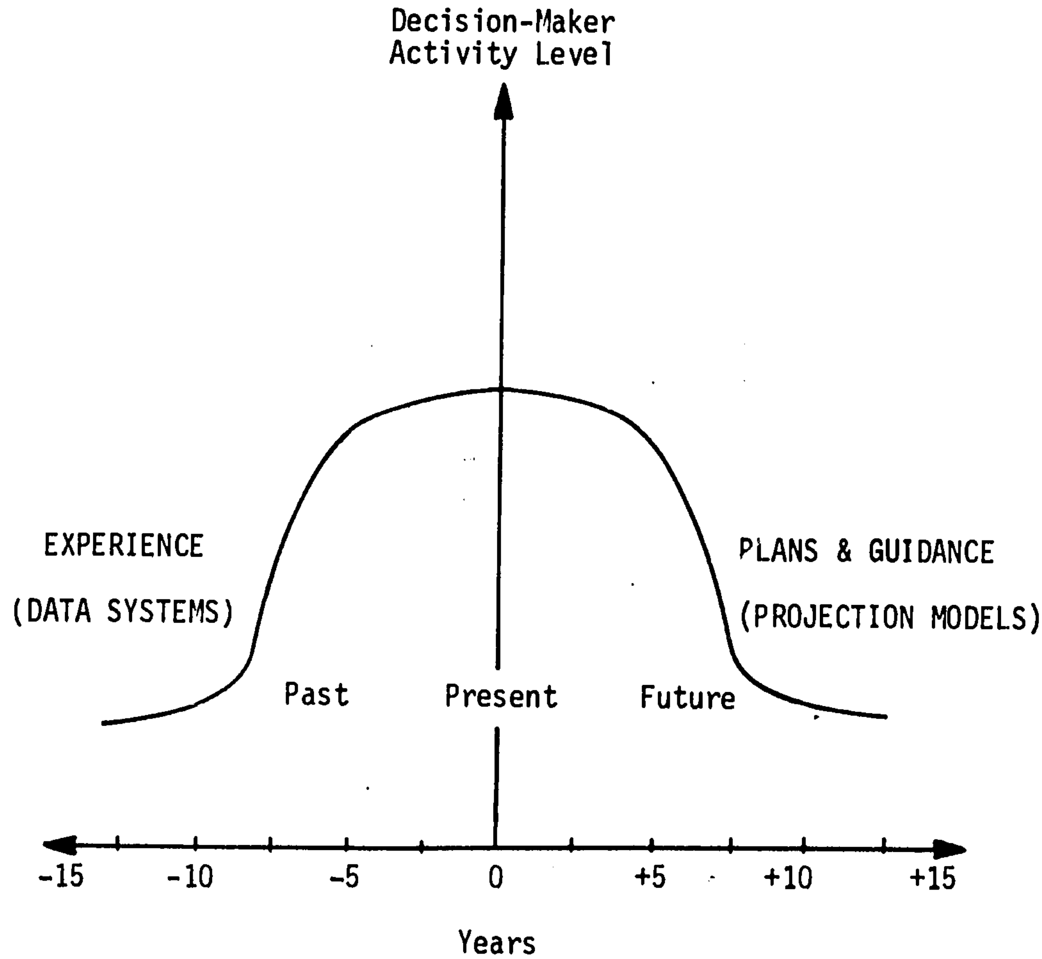

Figure 2. Preferred Time Orientation of Decision-Maker Activities

Figure 3. National Agricultural Decision-Making Capacity

can be divided into two parts: (1) the investigative side, which acquires, analyzes, and synthesizes information; and (2) the administrative side (including all bases of power), which decides and executes decisions and bears responsibility for consequences of action taken.

The term "investigative" is used throughout this book in the research sense of systematic inquiry and refers to the three broad functions indicated above. As used here, the term has no law enforcement connotation.

While a clear distinction can be made between the investigative and administrative functions, the distinction between investigators and administrators is often not so easy and, for that matter, not entirely necessary for our purposes. It is sufficient that in carrying out the problem-solving decision process, the responsibility and authority for each of the functions be vested in the individuals engaged in carrying them out. The mix of responsibility and authority varies, depending on organizational structure and the specific problem involved.

Administrative and Investigative Capacity and Functions

The administrative capacity contains the administrative and decision-making personnel involved in the decisions, action, and responsibility-bearing functions of planning, policy formulation, program development, and project design, execution, and evaluation having impacts on the agricultural sector. Many will be found within the organizational structure of the government agency concerned specifically with the agricultural sector and its problems; this agency is often known as the agricultural ministry [2]. Others may be found in a central planning agency, in other ministries having responsibilities with impact on agriculture--such as transportation, health, education, and finance; while still others will be found in the chief executive office, sub-administrative units such as provincial and village governments, and other organizations vested with the power to influence the course and development of the agricultural sector.

The main functions of administrative capacity include participating with the investigative capacity in problem definition, as well as decision-making, execution or action-taking, and responsibility-bearing [2, 28]. The ability of any administrative or decision-making unit in the administrative capacity to solve specific problems depends on (1) the ability of that unit to execute decisions and (2) the power of other administrative units and affected persons to react to the consequences of those decisions and actions. Power is expressed in covenants having to do with property ownership (market power), political alliances, military and police control, intellectual and moral leadership, and the influence of the press. The feedback of information from action-takers and affected persons to decision-makers is probably as important in solving problems as the input to the process from problem-oriented investigators.

A substantial proportion of a nation's investigative capacity vis-à-vis agriculture resides with the personnel manning its research and analysis agencies and in the academic community, which feeds disciplinary knowledge to the analysts. Among the other resources included in a country's investigative capacity are subject-matter models and associated general-purpose data systems. The main functions performed on the investigative side are observation and analysis, although obviously specific investigative units often include their own administration and at times furnish people to serve on the administrative side.

A distinction is necessary between various types of research and analysis found in a country's investigative capacity, since, while related, different types are carried out for quite different purposes. Further, an understanding of how the various components of the investigative capacity interact with the administrative capacity for problem-solving decision-making must be clear.

Types of Supporting Research and Models

Three distinct types of research and models can be found in the investigative capacity of a country. These are disciplinary, subject matter, and problem solving [28].

Disciplinary Research and Models

Disciplinary university departments of agricultural economics, political science, public administration, and of the different life and physical sciences are a part of the investigative capacity but also function partly outside of that capacity [28]. Disciplinary research and model development normally has as its purpose further extension of disciplinary theoretical knowledge and/or further disciplinary methodological development. Such research and model development may be of known relevance to solving practical problems; but, in some cases, it may be of unknown relevance [26]. Practical problem-solving is not an immediate objective of disciplinary work, mainly because few, if any, problems lie within the domain of a single discipline.

The disciplinary departments of a nation's agricultural colleges and universities also contribute to its analytical capacity with respect to agrarian problems. If the models of, say, an hydrologist, a plant geneticist, an economist, or a political scientist are useful as components in building subject-matter or problem-solving models, they are relevant. If they are not useful for these purposes, they are of unknown relevance, at least insofar as the specific problem or set of problems under consideration is concerned.

In general, the changes needed in the discipline of economics in going from one problem to another involving agricultural change seem to involve a series of minor, rather than large, single paradigmatic changes [36]. In Figure 4 the discipline of economics is diagrammed as Disc. 1, while soil science is diagrammed as Disc. 2. Both disciplines contribute to, but also extend outside of, the investigative capacity as they cover research of unknown relevance and include teaching responsibilities. Of course, many other disciplines could also be diagrammed. Because disciplinary models can be relevant, disciplinarians often regard their models as problem solving, even though their models are inadequate for handling the entire domain of any specific problem [25]. When this occurs, major credibility problems quickly arise between the disciplinarians and the decision-makers [20]. Similarly, subject-matter and problem-solving research often are discredited by the disciplinarian who concentrates on the disciplinary information and conceptualization in these models but who "sells" his results as problem solving [20, 22].

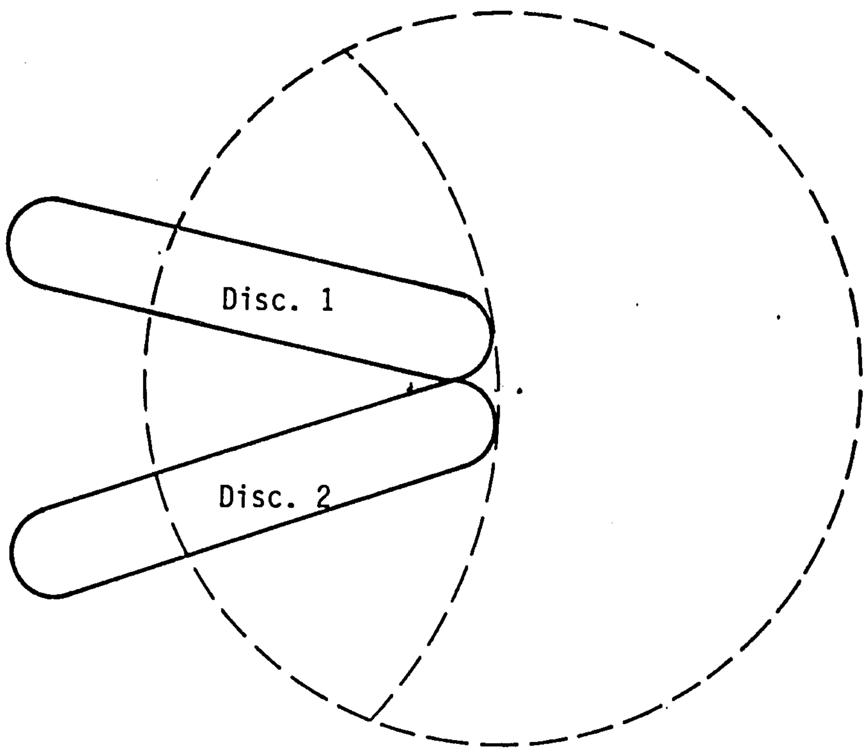

Figure 4. Relationship of Disciplines to the National Agricultural Decision-Making Capacity

The disciplinarian is likely to be offended by the multidisciplinary balance which must be achieved to develop models of relevance to problem solution [29].

Despite the dangers of misunderstandings and the shortcomings inherent in disciplinary research with respect to problem-solving, it is the basic disciplines which create the necessary components, models, and conceptualizations, data, and the techniques for subject-matter researchers and problem-solvers [47, 23]. Disciplinarians also provide the trained manpower to use the information models and techniques in building subject-matter models and in solving problems.

Subject-Matter Research and Models

Subject-matter research and models pertain to the increase in knowledge about an area of concern, such as agricultural sector development, land tenure, world food production and consumption, national transportation needs, or world energy requirements [28]. They are multidisciplinary and are specific to *sets* of practical problems. That is, each subject-matter area is relevant to many specific, interrelated problems requiring a given kind of knowledge from a variety of disciplines for their solution. However, such a problem in the set typically requires additional information of other kinds for its solution. Subject-matter research and models are also specific to the set of decision-making units responsible for solving specific sets of problems.

Subject-matter models or logical frameworks are important because they bring together bodies of knowledge--including data, information, theory, and methodology--which match a set of important problems and which can make a significant contribution to the solution of specific problems within the set. It is important to note that subject-matter models are not problem specific. Additional information, modeling, and analysis will need to be done to solve specific problems, while at the same time all information in the subject-matter model may not be used. Again, credibility may suffer, if subject-matter modelers and analysts attempt to sell their subject-matter work to decision-makers as problem-solving.

Along with, or as part of, subject-matter models are general-purpose data and information systems [3]. The data and information from these systems derive their meaning in large part from the subject-matter models they accompany. A common example is the national agricultural accounts model of a nation which is built around various concepts of input, output, distributive shares, industries (technology), political subdivision (institutions), behavior (human), and so forth. National agricultural account models and information systems are seldom capable in and of themselves of providing everything needed to solve a specific problem. Yet they make such significant contributions to the solutions of a broad spectrum of problems that most nations maintain or engage in establishing such models and associated information systems. Such a national agricultural accounts model and associated information system can be represented by Mod I in Figure 5. A general subject-matter model of the agricultural sector could be represented in this same figure as Mod II [31, 42, 48, 49]. The two models may overlap in part as shown, but the sector model may include much detail in agriculture not found in

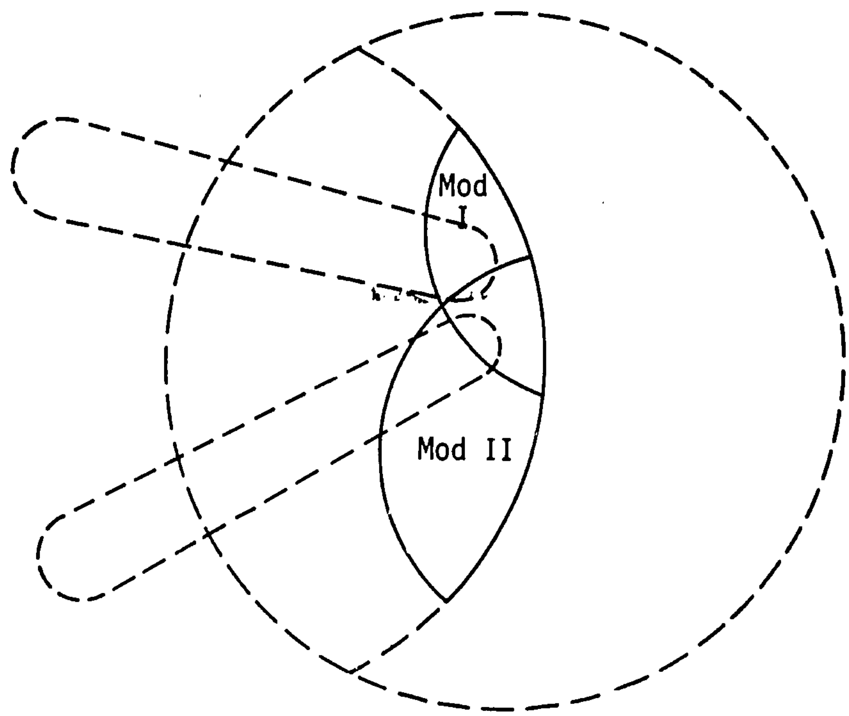

Figure 5. Relationship of Models to the National Agricultural Decision-Making Capacity

the national agricultural account model and, as such, can address a different, and perhaps larger, spectrum of problems.

Problem-Solving Models and Processes

Problem-solving models and analyses are problem specific and obtain credibility when they solve the problem for which they were created [20, 22, 28]. Like subject-matter models, they are multidisciplinary but are specific to a problem and to a decision-making unit. Such models typically include decision-makers, executives, and affected persons as sources of information, in addition to researchers and analysts. A specific problem, Problem I in Figure 6, has a domain which crosses both the investigative and administrative sides in the figure.

Usually practical problems have domains involving several different disciplines and require the use of knowledge and information from one or more of the disciplinary and subject-matter models available in the country's investigative capacity [28]. Typically, additional problem-specific information and modeling is necessary to contribute to the solution of the specific problem. The output from a problem-solving model is a prescription for action. A problem-solving model can lose credibility with decision-makers if its prescription is based on inadequate or inappropriate information and knowledge [20, 22].

Types of Research and Models Compared

Major controversies can arise among disciplinarians, subject-matter researchers, and problem-solvers when each attempts to evaluate the work of the other [20]. They simply have different criteria in mind for

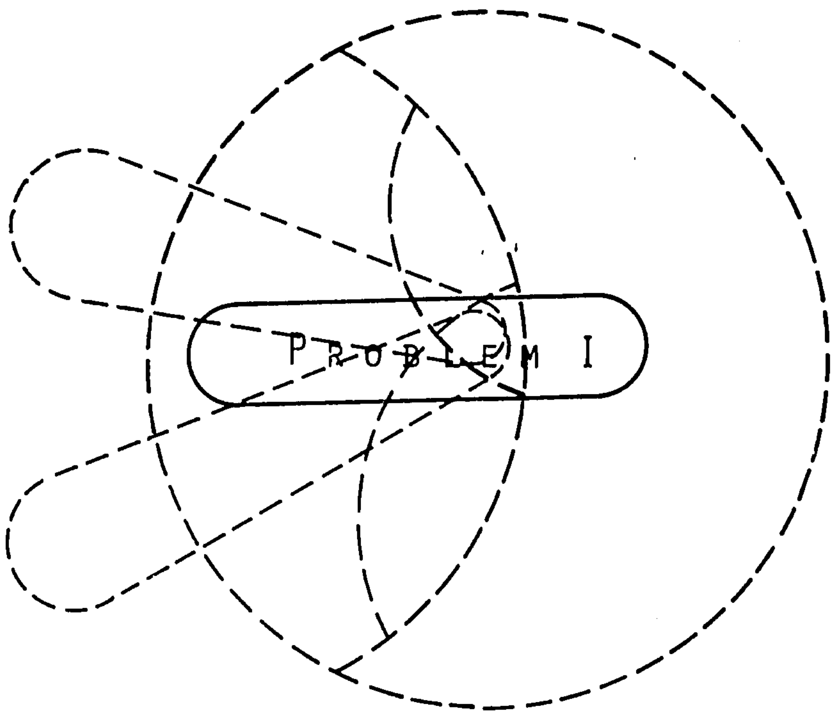

Figure 6. Relationship of Problems to the National Agricultural Decision-Making Capacity

their evaluations, since clearly they have different purposes at the onset. The purpose of the disciplinarian is to improve the theory, data, and methodology relating to the discipline. His criteria for evaluating research and models is whether it contributes to improvement and expansion of disciplinary knowledge. The problem-solver is concerned that the results of his research and models contribute to the solution of specific problems such that goods are attained and/or bads are avoided. The determination of the consequences of decisions and actions on affected persons, the ability to execute decisions, given the reality of the situation and the distributions of power among participants, are important. Subject-matter researchers and modelers have purposes and criteria falling between the disciplinarian and the problem-solver. They contribute to the stock of knowledge in a subject area. This knowledge can be useful in contributing to the solution of sets of problems within the subject-matter area, but only rarely can specific problems be solved without additional knowledge, data analysis, and synthesis. The multidisciplinary nature of subject-matter research and models is clearly recognized in providing knowledge useful in solving sets of problems. But the solution of specific problems and the concern for decision execution and power distributions are not included in the subject-matter-researcher's evaluative criteria.

The Decision-Making Process for Problem-Solving

Since problem solutions require decisions which are the result of the interactions of participants on both sides of the country's decision-making capacity, a detailed discussion of the decision-making process is in order [1, 5, 9, 10, 11, 13, 16, 17, 18, 19, 21, 30, 35, 38, 41, 52, 53, 54, 55]. Decision-making theoreticians and practitioners depict the steps in the decision-making process in varied but similar ways. One such view is depicted in Figure 7 as a sequential and iterative set of six steps, including (1) problem-definition; (2) observation and collection of data and information; (3) analysis to determine the consequences of alternative courses of action; (4) decision upon a course of action; (5) execution or action to implement the decision; and (6) responsibility-bearing, which includes monitoring and evaluation of the results and feedback of those results into the continuous decision process. The process is continuous and iterative in that the results of the decisions and actions must be constantly evaluated, issues redefined, observations extended, analysis reappraised, and decisions and actions adjusted accordingly in the light of new experience, new knowledge, and changing conditions.

Problem definition, the first function in the decision-making process, falls in both the analytical and administrative capacities of Figure 6 [28, 30]. Observation and analysis (functions 2 and 3 of the decision-making process) fall mainly in the investigative capacity, while decision-making, action, and responsibility-bearing (functions 4, 5, and 6 of the decision-making process) fall mainly in the administrative capacity. Problem definition involves the conviction or recognition that a situation can be improved within the purview and scope of responsibility of a decision-making unit.

A problem domain, such as Problem I, is specific to a decision-making unit, with power to decide and act while being required to bear

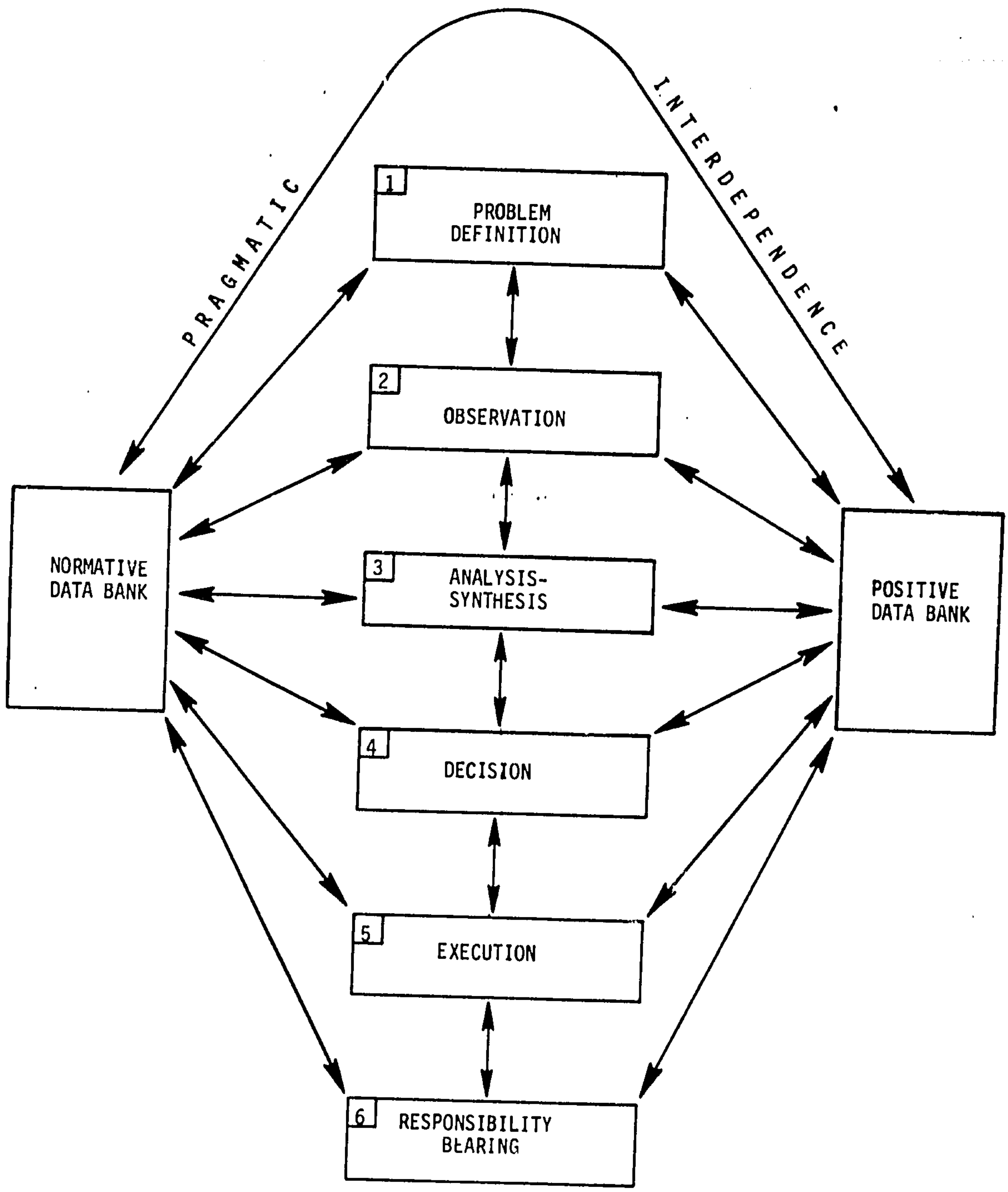

Figure 7. Decision-Making Process

responsibility [28]. On the investigative side, individual disciplines make their own special contributions to understanding the technical, institutional, and humanistic aspects of a problem. Problem definition will often require drawing on parts of more than one subject-matter model and, in addition, will usually require ad hoc conceptualization not existing as part of any established subject-matter model.

The second function in the decision-making process of problem-solving is observation, which includes data and information collecting and processing [3, 30]. Broadly speaking, institutional, technological, and human information are likely to be required [28, 30]. And these kinds of information are likely to be required in the past, present, and future tenses [30]. Expectations, data, and their formulation are inportant [19, 28, 30, 37]. Normally, much data and information, both normative and positive, are available in published form, in data banks, or in existing models. Often, however, primary data must be collected for a specific problem through the use of surveys, experiments, or solicitation of the judgment of knowledgeable people. The administrative side of a nation's decision-making capacity, including the feedback channels from affected persons, is often an important source of data and information. Another important feedback channel is the market, which sends a variety of messages to decision-makers about supplies, demands, needs, and other important variables. Another is the political system. For either to be effective, affected people must have power to originate messages.

What data should be collected and in what detail would be determined by equating the marginal costs of each kind of information with its marginal value in the context of the problem being solved. As the world is infinitely detailed, while budgets are finite and time is limited, attention must be concentrated on the most important [28, 30]. Disciplinary interests, subject-matter considerations, and personal penchants for a particular kind of data must give way to the opportunity cost principle in allocating observation efforts to the different parts of a problem domain.

The third function is analysis [30]. Occasionally, strictly disciplinary models and empirical work can contribute to problem solution. Subject-matter models, such as agricultural sector models and national agricultural accounts in the investigative units, often provide components useful in modeling or conceptualizing the domains of a particular problem. Other components are typically created *in situ* or are "borrowed" from other subject-matter models. Data, information, and model components, as well as talent, often can be obtained from academicians, consultants, and advisors not normally part of the particular investigative unit. In addition, important and useful data and information can be received from the decision-makers themselves. Economizing is necessary in conceptualizing the domain of a problem. Optimal degrees of refinement can be defined by equating costs and returns at the margin for different components in the context of the specific problem being solved.

The fourth function in problem-solving is decision [30, 31]. In this function the analysis and synthesis of the relevant theories, data, and information are translated into a prescription for action to take for solving the specific problem at hand. The decision may maximize, in the sense that it might indicate which open course of action is "the best" or, perhaps, "the least bad" to take [38]. The formal analytical components of the model or concept of a problem domain need not contain a maximization component, if the decision-maker is willing to serve in the total model as an informal component. The same is true with respect to action-taking model components and functions. Even when the model of a problem domain has a maximizing and action-taking component, the real decision-maker and executives are likely to reserve the right of overriding such components and, hence, still be components of the overall model.

The fifth function in problem-solving decision-making is action or execution [2, 30]. This is an essential step in problem-solving; for without action, decision is unreal and tentative. The ability of the decision-maker to act to implement the decisions affects the detail with which it pays to model or conceptualize a problem and its solution. A so-called "solution" which cannot be implemented is not a solution.

The sixth and final function in the problem-solving process is responsibility-bearing [30]. Responsibility is borne by decision-makers, action-takers, and affected people. Those who bear the consequences of actions may have power to originate and transfer feedback messages and to participate in decision-making. The extent to which decision-makers bear responsibility, monitor consequences, and are required to receive feedback messages partially determines their participation in observation and analysis of the domain of a problem and in deciding upon its solution.

Normative, Positive, and Prescriptive Knowledge

Throughout the decision process both normative [38, 44, 50] and nonnormative, or positive, knowledge must be collected and combined into prescriptive knowledge on the basis of some decision rule to establish goals (about future actions) or to determine the right actions (present) [38, 40]. Several of the terms in this statement are used throughout the remainder of the text with precise meanings. To avoid ambiguity, these terms must be defined.

Normative knowledge deals with concepts of value [12, 40]. It pertains to the goodness and badness per se of a condition, situation, or thing. A concept of goodness exists when a condition, situation, or thing is conceived on the basis of experience and logic to be good; that is, to contribute to the attainment of human interests and purposes [44]. Conversely, a concept of badness exists when a condition, situation, or thing is conceived on the basis of experience and logic to be bad; that is, to frustrate or detract from the attainment of human interests and purposes. A shorthand means of indicating values is to refer to *goods* to be attained and *bads* to be avoided.

Decision-makers deal with both monetary and nonmonetary values in a socio-economic context [1, 24, 27, 30, 38, 39]. Economics is concerned with attainment of nonmonetary as well as monetary values. The error of treating nonmonetary values as noneconomic, for example, would eliminate consumption and welfare economics from economics! It is difficult to conceive of a single value about which efficiency considerations do not arise when one is trying to attain it (if it is good) or avoid it (if it is bad). It is equally difficult to think of a purely economic or a purely social value. Attainment of economic values is attended by social consequences; and, conversely, considerations of efficiency (economic) are involved in attaining or avoiding social values. The dichotomy of economic versus social values is thus rejected.

Nonnormative, or positive knowledge, is information about a condition, situation, or thing not pertaining to its goodness or badness. The term "nonnormative" is used as a synonym to the term "positive" to highlight a rejection of the positivistic notion that normative facts, truths, and experiences do not exist [12]. Nonnormative, or positive knowledge, is usually thought of as pertaining to the physical and biological, or "hard" sciences; however, such knowledge is also found in the social sciences--for example, about institutions and people. In this construct, both normative and positive facts exist and the fact-value dichotomy is also rejected.

Both normative and positive knowledge are necessary and must be used together to reach prescriptive knowledge to define and solve practical problems with appropriate actions. Prescriptive knowledge pertains to "what ought to be" and how "what ought to be" ought to be accomplished [1, 27, 30, 38]. The task of the decision-maker is to maximize the difference between good and bad. Right actions are constrained by what is conceived to be feasible in reality.

Prescriptive knowledge is difficult and often uneconomic to bank because of the specificity of problems. When a problem occurs repeatedly and can be solved by a rule, the prescription becomes something of a skill, a "recipe" or law-governing action. Skills can be banked in decision-makers, executives, foremen, supervisors, and analysts. Recipes can be written out as instructions to be followed. Laws can be promulgated. Skills, recipes, and laws are relative to both values and positive information about what is possible.

Philosophically, pragmatism is based on the metaphysical presupposition that normative and positive truths are interdependent and that workability is a test of the truth of a concept [14, 15, 46, 51]. Pragmatism is concerned with prescriptive knowledge--skills, recipes, rules of conduct, law--for the solution of problems. Prescriptive knowledge is generated through relating the positive to the normative in the context of a problematic situation. Thus, the pragmatic interaction loop between the two data banks in Figure 6 represents, in one sense, the skills, recipes, rules, and laws available for problem-solving decision-making and, in another sense, the pragmatic assertion that normative truth and nonnormative truth depend mutually on each other.

A prescription describes a right action [38]. The concepts of right and wrong depend both on normative and positive concepts about past, present, and future. Thus, it may be wrong to do what is good because something better might be possible. Conversely, it may be right to do something bad if it is the least bad which can be done. It should be clear from the discussion and Figure 6 that the decision-making process is prescriptive and that normative and positive knowedge are the two supports upon which the decision-making process rests, the absence of either of which causes the process to fail.

A simple illustration of prescription is one in which the problem is to determine the "right" amount of nitrogen to apply and the "right" yield of corn to attain. The positive production function relating corn yield to nitrogen applied is transformed into a gross income or value productivity function through multiplying yield by price (a measure of value). The total cost function is the sum of fixed cost and the value of nitrogen applied (quantity times price). In this example, income is *good* and cost is *bad*. The right action is defined as applying the amount of nitrogen which maximizes the difference between *good* and *bad*; the decision rule is to maximize profit, since perfect knowledge is assumed. This simple example illustrated in Figure 8 is based on simplifying assumptions, many of which are not met when public decision-makers must deal with complex development problems involving technical, institutional, and human changes taking place under uncertainty. When the simplifying assumption of perfect knowledge is not met, the simple decision rule is not applicable.

Public decision-makers are usually concerned with the attainment of multiple desirable consequences (goods) and the avoidance of multiple undesirable consequences (bads) under conditions of imperfect knowledge. Prescribing right actions under these circumstances becomes much more difficult and complex than in the simple example illustrated above. Four preconditions must be satisfied before a maximizing decision can be made [1, 28, 29]. A precondition for such a decision is agreement on an appropriate decision rule [9, 13, 16, 18, 19, 30, 55]. Much of the effort expended by the decision-maker during the decision-making process is on determining the appropriate decision rule. Also, a normative common denominator (such as dollars or utility) must be available to permit the summation of the diverse *bads* and their subtraction from the

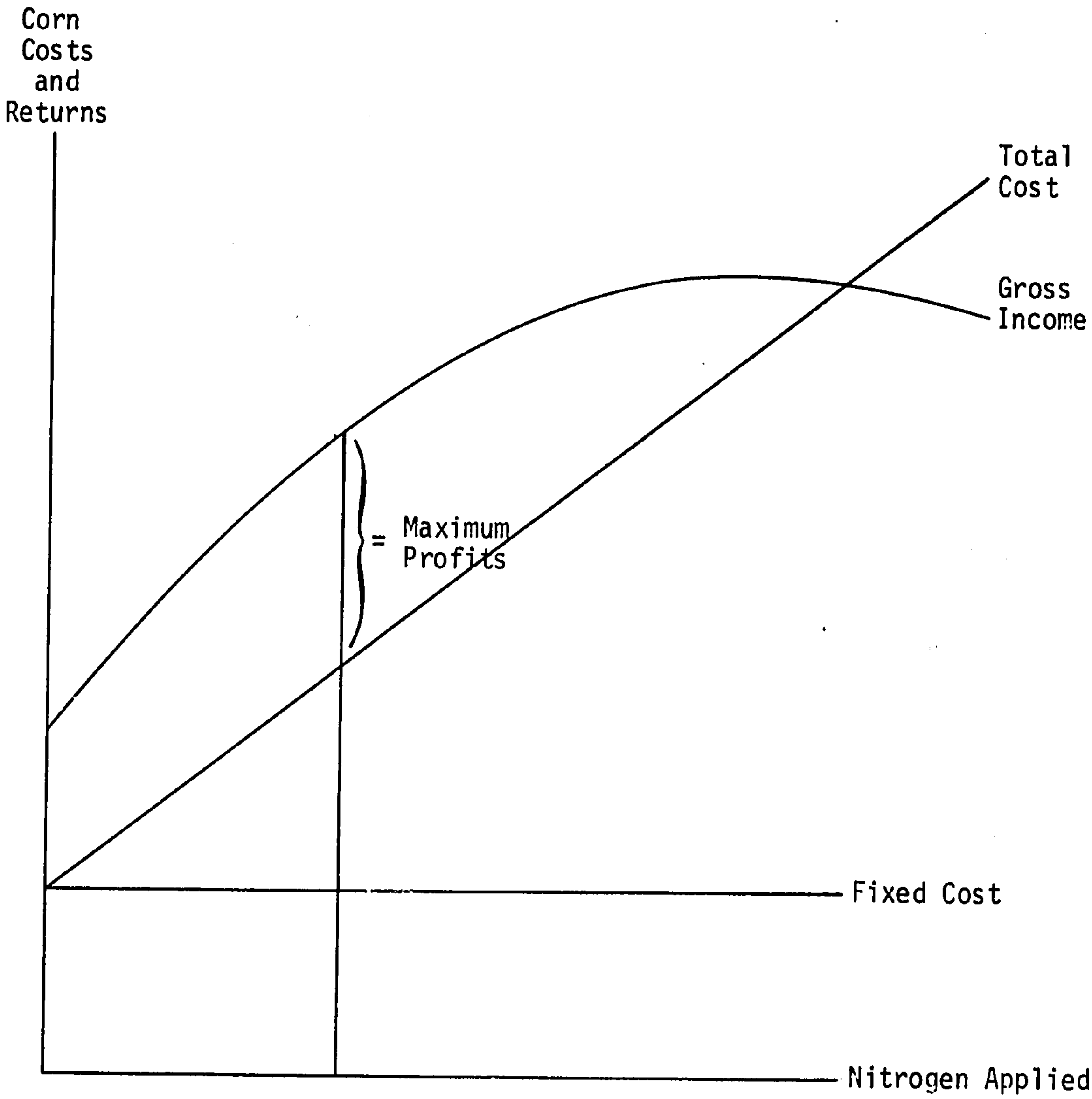

Figure 8. Value Productivity and Input Cost Functions to Determine Most Profitable Amounts of Corn to Produce and Nitrogen to Use

summation of the diverse *goods*. Further, the normative common denominator must have interpersonal validity if *bads* imposed upon one person or group are to be subtracted from the *goods* conferred on another person or group [1]. Finally, the order in which actions are implemented must either be unimportant or be capable of ranking in the order of their decreasing net advantage per unit of sacrificed *good* or incurred *bad*. In mathematical terminology, this means that the second-order conditions for existence of an optimum must be established. Many problem-solving research efforts involve great expenditures of time, effort, and money to establish the normative preconditions for maximization and the positive preconditions constraining action, while the actual maximization requires only a minor effort [31, 48, 49].

Reaching a prescription generally involves some sort of maximization, although the maximizing decision rule may be much more complex than merely maximizing the difference between goodness and badness. Under imperfect knowledge, decision-makers follow various decision strategies, such as bringing the consequences of their actions to minimum acceptable levels, maximizing the average (expected) difference between *good* and *bad*, doing that for which the worst that could happen is better than the worst for any other possible action, bluffing, going to war, flipping a coin etc. [9]. In acquiring, analyzing, and synthesizing information and data to project the consequences of alternative courses of action, it is appropriate to utilize the resources available to the point where the marginal costs of further iteration of the process would be greater than the marginal return in solving the problem [30]. The decision can be made on the basis of information and knowledge available at that point, the decision executed, and the consequences of the action borne.

Perfect knowledge with respect to the four preconditions for problem-solving decision is impossible. Normally, even to approach perfect knowledge would be prohibitively expensive. In the absence of perfect knowledge, power (market, political, police, and so forth) is embedded in various covenants as a necessary part of a decision rule [28]. Because the perfect knowledge required for concensus is infinitely expensive, the use of power eventually becomes cheaper than the investigation, analysis, and research necessary to produce new knowledge. Another optimum has to do with the distribution of power. Until a certain degree of power equality is established, feedback is thwarted by absolute control and possible repression. On the other hand, complete equality in the absence of perfect knowledge may lead to indecisiveness. Thus, optima exist with respect to both the certainty and stability of power distributions [28]. Uncertainty and instability lead to a misunderstanding and/or conflict, while undue stability and concentration of power lead to neglect of problems and eventually to costly catastrophic change. Political, military, and socio-economic institutions must be responsive and adaptable to the changing realities to prevent the consequences of imbalances in power distributions.

Models in the Decision-Making Process

In spite of the uncertainty inherent in the process, decision-makers responsible for social and economic development must make decisions (even no decision is a decision to do nothing); and in making those decisions, they must acquire information, data, and knowledge (imperfect as it may be) concerning the possible future consequences of alternative courses of action [28, 30]. In arriving at a decision for action (steps 4 and 5, Figure 7) the decision-maker and his investigators must put the relevant data and information which have been collected (step 2, Figure 7) into a logical framework from which inferences can be drawn as to the important consequences of alternative courses of action (step 3, Figure 7). This framework--no matter how simple or complex, informal or informal, impersonal or personal--can be regarded as a problem-solving model. In projecting the consequences of alternative courses of action, models are used extensively, since direct experimentation on the system is often uneconomic, dangerous, or physically impossible [42]. These models typically range from intuitive, mental images of the system through written or verbal descriptions to complex, computerized mathematical models [5]. Further, more than one type of model may be used to provide input for any one decision. For example, a computerized mathematical model may be used to make projections of economic variables, while projections of political variables may be made with a mental model. A combination of such models is a necessary component in the total problem-solving model.

A model of whatever kind is an abstract representation of a system, socio-economic or otherwise. It is abstract because it cannot deal with all aspects of reality [12, 35]. Given the intended purpose for which the model will be used, only characteristics of the system relevant to that purpose can be modeled; and even these characteristics will only be modeled to the level of detail sufficient for that purpose. Thus, assumptions and simplifications--what to put in the model, what to leave out, what to aggregate, how much to aggregate--are a necessary and inescapable part of modeling, whether a simple mental image or a complex computer program is being used.

The quality of a decision depends in large measure on the quality of the process undergone in arriving at that decision. The ability to acquire, assimilate, synthesize, and analyze data, information, and knowledge in an appropriate logical framework or a model will determine the quality of that process [3, 10, 11, 28, 30]. Thus, a necessary condition for enlightened public decision-making is a broadly based and highly developed investigative capacity.

A General System Simulation Approach

The general system simulation approach to agricultural sector development decision-making involves both the administrative and investigative sides of a country's decision-making capacity depicted in Figure 3 [7, 8, 31, 42, 48, 49]. It facilitates and depends on strong and continuous interaction among administrators, investigators, and affected people, as participants in the decision-making process. It is eclectic with respect to philosophies, data and information sources and types, model types, the use and nonuse of various maximizing techniques and assumptions, and dimensions [29].

The approach gains its credibility in part from the participation of the decision-makers, along with the investigators in the process, and in part from its eclecticism, which is similar to that practiced by the decision-maker himself [28, 29]. While it is useful when applied only with informal mental models or paper-and-pencil analyses, the more formal the models used, the more comprehensive and specific the results. The core of the logical framework used in the approach is a model of the structure and processes comprising the system within which specific problems or problem sets are encountered and about which decisions must be made. When simple maximizing behavior is being predicted or prescribed, the appropriate decision rule can be incorporated in the formal model. When a more complex decision rule is indicated, it must be determined in interaction with, but outside of, the formal model [28, 29]. While the approach is applicable to all types of research and modeling, it is particularly applicable to the subject-matter and problem-solving types.

The example cited in this book focuses on a subject-matter model of an agricultural sector developed for national-level planning and policy decision-making. The formal part of the model is computerized. It is composed of several components which can be run separately or in concert. It, or its parts, can also be modified and extended with additional information and modeling to focus on specific problems. Thus, problem-solving research and analysis is feasible and easily adapted. A more detailed discussion of the general system simulation approach follows.

As governmental decision-makers confront problems for which their mental and paper-and-pencil models are inadequate, they often turn to professionals from appropriate disciplines to build more complex models of reality, based on theoretical constructs and using mathematical representations of relationships to formalize the logical framework. Complex model-building and mathematical representation became much more feasible with the introduction of large-scale electronic computers having the ability to perform extremely rapid calculations and to keep track of literally hundreds of variables and their interrelationships [31, 42, 48, 49].

Mathematical models of economic subsystems of socio-economic systems are being used in a variety of research, planning, and policy applications by both private industry and government, while mental and verbal models are still used heavily for analysis of political and social phenomena [20, 22, 27, 28]. Economic theory is useful, as it deals with quantifiable variables; and recorded data are sufficient for some work with the relevant, structural, and process relationships. Gaps in economic theory and data exist, however, particularly in the areas where economic and social phenomena are closely interrelated, such as in rural-urban migration and decisions of the farm unit as both a producing firm and a consuming household. A formal logical framework or mathematical systems model is needed which takes account of the structure, processes, and interrelationships of the total agricultural sector and its interactions with the rest of the economy and which is capable of addressing a broad set of problems related to agricultural sector development [31, 48, 49].

Such a model must combine several characteristics not often found together in more limited models. First, it must be broad in its scope of analysis and general with respect to philosophies, techniques, and kinds and sources of data and information.

We have already discussed the broad philosophical orientation required for subject-matter and problem-solving research. It is sufficient at this point to reiterate the need for subject-matter and problem-solving investigators, as well as decision-makers, to draw from various philosophical positions, including normativism, positivism, and pragmatism, as appropriate.

The general system simulation approach makes use of a variety of techniques. Specific kinds of mathematical models using specific techniques have their own relative advantages and disadvantages. For example, programming models can determine the choice of actions which will optimize the attainment of a given objective, subject to constraints. Such models can be useful when the preconditions for maximization discussed above are met. On the micro level, such as a farm firm or other decision-making unit, such models can sometimes be used, since a single objective or combination of objectives may sometimes be reasonably assumed and interpersonal validity may be less of a problem. If a region rather than a single farm is being modeled, aggregation problems may be troublesome. On the macro level, where, for example, a sector or an economy is being modeled to optimize development objectives, preconditions are still harder to meet and aggregation problems become severe, thus making the use of programming techniques even more questionable than at micro levels [3].

Another specialized technique often used to perform policy simulations is econometric analysis of sets of simultaneous equations. The parameters of such systems are statistically estimated directly from observed and recorded time series or cross-sectional data on the performance of the system. These estimates are presumed to represent the parameters of the system being modeled. Unfortunately, time series and cross-sectional data, especially in developing countries, are often scarce, poor, or nonexistent; hence, a model based solely on such data may not represent the real-world systems as well as models based on additional types and sources of data. In addition, statistical estimation procedures place severe restrictions on the form of mathematical equations in econometric models. Finally, a model based on historical data and which may be a fair representation of a system in the past will not necessarily be so in the future, particularly in planning development where technological, institutional, and human changes are the objects of the exercise [7, 23].

Other specialized techniques, such as input-output analysis, benefit-cost analysis, critical path analysis, and so forth, like programming models, are applicable only for particular purposes and only under special circumstances--where good data exist, where an objective function can be defined, or where a particular structural form (linear, quadratic, etc.) is justified. While these models appear rather rigorous, they often lack credibility with decision-makers, as they are very selective of the sources and types of data they will accept, as well as unduly specialized in other ways. Later we will discuss the close relationship between credibility with decision-makers and the concepts of validation and verification. These models often fail to provide decision-makers with answers concerning the wide array of consequences to be expected from a specific course of action, nor can they easily be adapted to an assessment of the consequences of several alternative courses of action, particularly if simultaneous changes in several policies and programs are involved. Thus, credibility gaps develop between many governmental decision-makers and their professional investigators with respect to the usefulness of these kinds of models.

In the general system simulation approach, any of the techniques discussed above, along with various mathematical modeling and analysis and simulation techniques from systems science, are employed, as appropriate and in various combinations, dedepending on the characteristics of the system being modeled and the requirements for decision-making information.

A specific technique used to model a specific process or behavioral characteristic is chosen because it is seen as being most appropriate for the job. Thus, techniques and knowledge are drawn from demographers, farm management researchers, public administration analysts, economists and econometricians, statisticians, engineers, systems scientists, operations researchers, and physical and biological scientists, as required, to improve the model until the value of the improvement no longer exceeds its cost.

Kinds and sources of information and data used in the models vary according to availability and model requirements. They include time series and cross-sectional data, opinion and judgment of experienced professionals and practitioners, experimental and survey results, and "guesstimates." A major source of information, particularly of the normative type, is the decision-maker himself, thus requiring a great deal of interaction between the investigators and the decision-makers.

Second, the model must be capable of tracing the consequences of specific decisions and policies across a wide variety of dimensions of interest to decision-makers. Since human, institutional, and technical change through time are of major importance, primary emphasis is on the time dimension. Other dimensions of likely importance include space, demography, economic function, commodity, input, etc.

Third, the subject matter dealt with by the model must be viewed as a system comprised of subsystems and itself as a subsystem of a larger system. The logical framework or model thus described is conceptualized using a general system simulation approach.

A building block concept is employed in which relatively self-contained economic, technical, or biological functions or processes take place within specified model components [42]. As specific problems are identified, the appropriate building blocks or model components can be chosen and linked in the proper configuration to provide analytical input to specific problem solutions.

The availability of large, high-speed electronic computers with software components adaptable to economic and social science research provides an efficient means of implementing the approach. In particular, the use of a computerized model enables postulation and projection of many more variables and complex interrelationships than are possible with informal paper-and-pencil, verbal, or mental models.

Combining the computer with the methodology and orientation of the general system simulation approach and with the conceptualization of problems within a sector framework provides a formal, computerized, general system simulation model of an agricultural sector with the capacity to address a broad set of problems of concern in agricultural sector development. Such a model can be a valuable analytical tool in helping decision-makers in their planning, policy formulation, and program development activities. Further, such a model can be of use over a virtually indefinite time period, with periodic updating and modification to continue to accurately reflect the system under consideration.

Because it is designed to provide input to a set of problems concerning agricultural sector development, it is a subject-matter model [28]. It is both broad enough and detailed enough, however, that in most cases relatively minor modifications and extensions allow all or parts of it to be used in specific applications to solutions of specific problems in the problem set for which it is designed. It is used in an iterative and interactive context, with investigators and decision-makers carrying out the funcions of the decision-making process.

Conceptually a formal system simulation model of an agricultural sector focused on planning and policy analysis can be viewed in the following general mathematical form [42, 48, 49]:

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

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

where:

$\psi(t)$ = a set 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.

$\pi(t)$ = a set of output variables indicating system performance, such as profit, income, growth rates, balance of trade, employment, nutrition, etc.

$\alpha(t)$ = a set of parameters defining the structure of the system. These parameters usually regulate rates of change between levels, through time, or through space, such as input-output coefficients, technical coefficients, behavioral response parameters (these may or may not presume maximization), price and income elasticities, migration rates, birth and death rates, etc.

$\beta(t)$ = a set of environmental variables, such as world prices, weather, etc.

$\gamma(t)$ = a set of policy instruments, such as price controls, tax policies, production campaigns, investment alternatives, etc.

The state equation (ψ) is a general representation of the difference equation formulation of the system model describing the state of the system at discrete points in time. The output equation generates the variables (π) necessary in the model application stage to evaluate, in terms of the goals specified in the problem definition, the performance of the system over time under various policy alternatives. Both normative and positive knowledge are incorporated into the model [29]. In some cases, where simple maximizing behavior is observed, such behavior is easily modeled. In other instances a model can be run in an optimizing mode to find optimal policies, programs, or project organizations. When a formal model is not run in an optimizing mode, informal interactions with decision-makers and/or affected people are required. When modeling behavior or finding optima, maximization involves the use of decision rules and associated political and socio-economic covenants. The result is in effect a mixed man/computer model.

The formal model, using the general system simulation approach, is realized in the hundreds or even thousands of parameters and structural and behavioral relationships incorporated in the model. Actual specification of the model requires (1) precise description of the model components; (2) explicit algebraic, difference, and/or differential equations to represent the structures, processes, and mechanisms within components and the linkages between components; and (3) programming for computer implementation.

Such a model consists of essentially three parts. The first is the logical framework, which attempts to reflect the structure and processes of the real world [4, 6, 34, 43]. This logical framework is explicit in the model in various forms, ranging from a verbal description facilitated by block diagrams, through a set of mathematical equations, to a list of FORTRAN subroutines and statements which spell out the equations and linkages in an operational, computerized model. In general this is the model structure. The more comprehensive and complex the model representing the complexity of the real-world system, the greater is the detail and complexity of the model structure.

The second of the parts making up the model are the estimates of the parameters or the coefficients indicating the quantified values of the linkages in the model [4, 6, 33, 34, 43]. The coefficients are determined, found, or estimated for the most part outside the system's model structure. Any and all of the traditional parameter-estimating techniques are used, as appropriate. None is precluded--none is required. And data and information are brought to bear from whatever sources are available and relevant.

The third part of the model is the data reflecting the initial conditions for the base period from which the model begins its simulation. While interrelated, these parts may be viewed, worked on, and improved separately. Thus, model structure can be changed to more accurately reflect the real-world system without changes in the estimated coefficients or the initial condition data. Similarly, more accurate, more reliable estimates of parameters can be incorporated into the model without changing the structure or the base-period data. And finally, base-period data can be updated or changed to reflect greater data accuracy without changing either parameter estimates or structure. For broad-guaged model development, improvement, and application, work on all three fronts must be continuous. If the model is not run in an optimizing mode, a fourth part of the model (or necessary addition to it) is the decision-maker and affected people with whom the investigators must interact if the model is to be used for problem-solving.

Figure 9 depicts both the formal and informal modeling components. The formal modeling process has three phases: the problem-definition phase (roughly analogous to steps 1 and 2 of the decision-making process depicted in Figure 7), the system simulation phase (roughly analogous to steps 2, 3, and 4 of Figure 7), and the policy formulation and implementation phase (roughly analogous to steps 4, 5, and 6 of Figure 7). The informal interaction discussed above appears at the top of Figure 9.

As with the decision-making process, normative and nonnormative information is required [34, 37, 44]. When information is deficient, the consequences of such deficiency can be determined and new information can be sought, if judged to be worthwhile. The whole process is highly iterative; and decisions are a result of the interactions between the information, modelers, analysts, and the decision-makers themselves.

The problem-definition phase entails the explicit and precise identification of values ("goods" and "bads" or system performance criteria), relevant alternative policy instruments, and system and policy constraints [28]. An optimizing analysis may indicate the level at which the nation should expect its agriculture to feed itself and the rest of the nation and to support nonagricultural growth by supplying

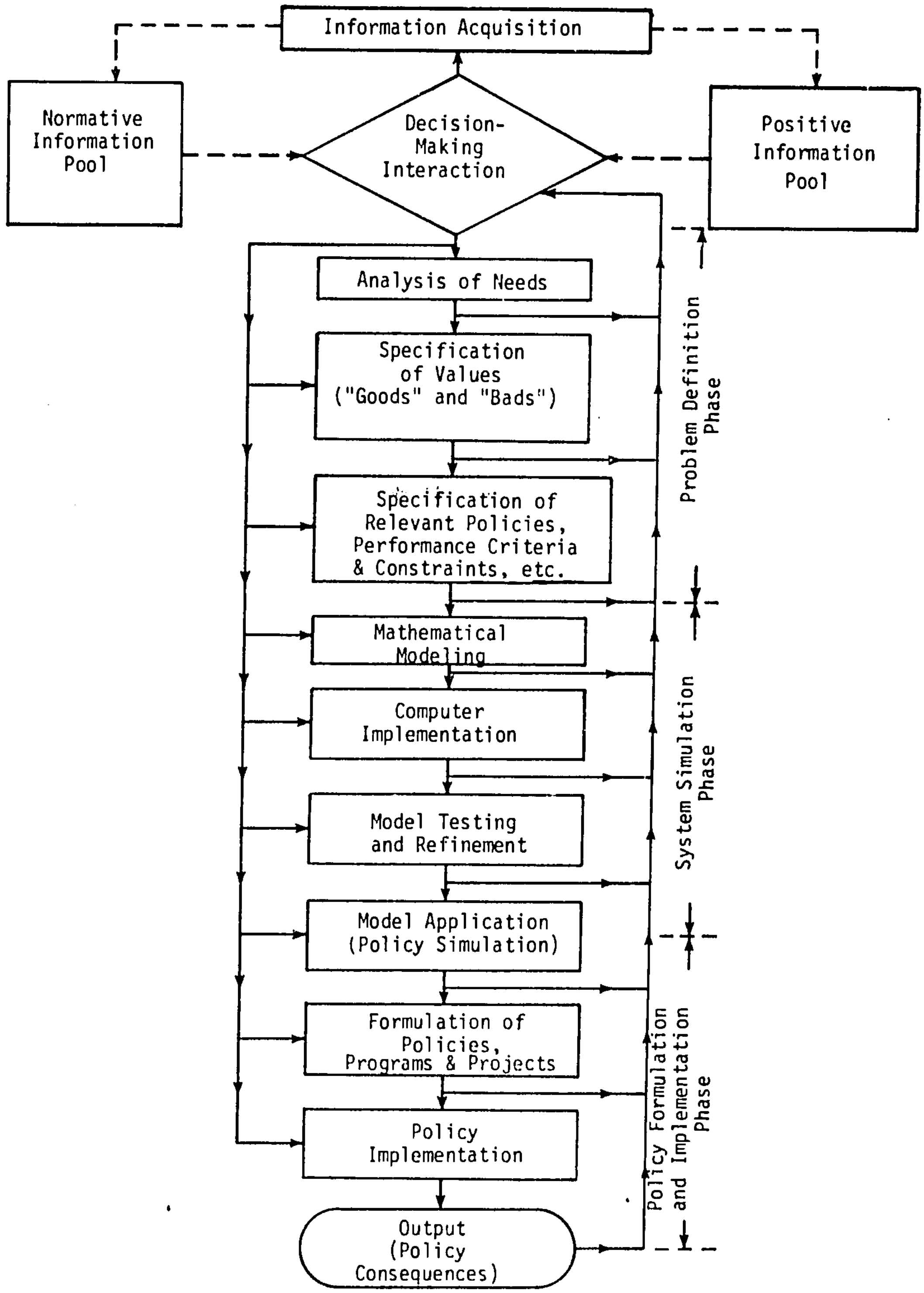

Figure 9. System Simulation and the Decision-Making Process

resources and demanding nonagricultural goods and services. Values may specify that increasing income is good, but inequitable distribution of income between agriculture and nonagriculture and within each of them is bad; agriculture supplying labor to nonagriculture is good, but urban unemployment is bad; etc. Given the values, alternative policies might be devised to increase the productivity of agricultural resources, to improve the efficiency of the marketing and distribution system, and/or to promote import substitution and export production in both agriculture and nonagriculture, etc. [45].

Alternative instruments for carrying out such policies might include the use of tax rates as incentives and as sources of revenue to finance other programs and projects, production campaigns to increase the efficiency of agricultural resources, irrigation and mechanization programs, producer pricing policies, setting foreign exchange rates and import quotas, etc. Relevant performance criterion variables might include levels and growth rates of GNP, per capita income, calorie and protein consumption, trade balances, unemployment, etc.

The above will be recognized as nothing new to development planning and policy analysis. Its formalization is necessary, however, to determine what sort of model to build; that is, what subsystems and components should be identified and the level of aggregation desired of each, policy instruments to include, the performance criteria to be generated (π in the above equations), etc. The model is then built and programmed for computer implementation.

The most important reason for developing a simulation model (in this context) is to provide a low-cost means of exploring the consequences of a wide range of alternative plans, policies, or management strategies. One simulation experiment can lead to the development of a new and better design, 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 and mutually reinforcing and to show how resources could be effectively used to solve the basic problem (as defined).

Policy simulation results may suggest further alternatives to be tested in an iterative process of policy formulation. Eventually, a decision is made to implement a particular set of policies [9]. Most often the decision is based on interaction between investigators and decision-makers, rather than solely on a formal model operating in a maximizing model [2, 28]. The real-world consequences of that decision will influence later policy formulations and may even lead to a redefinition of the problem, thus continuing the iterative decision-making process, with further modeling integrated as part of the process [14, 15, 51].

Credibility

A prerequisite for use of any model for problem-solving purposes is acceptance by decision-makers [28]. Model-builders and disciplinarians often expect credibility and acceptance by decision-makers to be achieved through simple validation and verification of their highly specialized models. This is not sufficient for decision-maker credibility, as has been painfully proven over and over again for specialized models built by investigators using specialized techniques and data [7, 29]. Even though such models pass the usual validation and verification tests, they are often rejected by decision-makers as irrelevant, too complicated, too narrow, or just plain wrong. In a broader, very legitimate sense, they are neither validated nor verified.

The concepts of validation and verification have had a wide variety of meanings among scientists [4, 6, 12, 33, 44, 50, 51]. Usually, validation has meant testing a concept, theory, or model for internal logical consistency [6]. Verification generally means testing a concept or model with respect to its ability to reflect accurately the real-world situation or phenomenon it is intended to represent through its capacity to track historical data and to project accurately the behavior of important variables of a system into the future [6, 33]. Validation is a test of coherence, while verification is a test of correspondence. Models and the concepts and theories used to build them must also pass the test of clarity in order to achieve credibility with decision-makers. That is, the model's concepts and theories must be explainable and understandable to those who use them if they are to be accepted; scientifically, they must be clear and unambiguous *before* the tests of coherence and correspondence can be applied. Finally, they must pass the test of workability when used to solve problems [46, 51]. The workability test evaluates the prescriptions based on the model in terms of how well they perform in the real world, judged by the good results achieved and bad consequences avoided. Simply stated, the workability test requires that models help *solve problems* of real-world decision-makers, not just answer positive and normative *questions* of disciplinarians or other curious people--workability is related to the prescriptive [28, 38, 40]. The utility of a model increases with success in passing and decreases with failure to pass these tests.

A specialized model can pass the validation (coherence) test in the narrow sense but still flunk it in the broader sense in which a decision-maker views the situation because of the omission of logic required to model the entire domain of the problem. This happens, for instance, when an economist omits essential technical or institutional concepts known by decision-makers to be important. A model can also pass the verification (correspondence) test in the narrow sense but flunk it in the broader sense if it does not consider or project variables known by decision-makers to be relevant. It also flunks the test of clarity if it is not clear and transparent enough to be understandable and explainable to the decision-maker. Finally, it may flunk the workability test if the prescriptions derived from it are known by the decision-maker to be inappropriate or insufficient.

It should be clear that establishing credibility is not a one-time procedure, but rather an iterative process that goes hand in hand with adapting and utilizing models in a variety of problem-solving applications [28, 30, 46, 51]. Utilization feedback increases credibility and credibility increases utilization. The tests of coherence, correspondence, clarity, and workability need to be applied repeatedly in the development, institutionalization, and utilization of models. Intensive and continuous interaction among model-builders, analysts, and decision-makers plays a key role in performing these tests.

Unlike more specialized disciplinary models based on specialized data, eclectic subject-matter and problem-solving models, using the general system simulation approach, are more general with respect to kinds and sources of data and information and techniques used in their construction. Some of the data in such models are experimental. Often results from many different experiments are involved. Other data used are more judgmental, with different levels of reliability. Both positive and normative data are used. Still other data are from time series, others are cross-sectional, while still others are synthesized or simulated from various combinations of data. The situation is further complicated by the use of several kinds of information in complex computations to foresee attainment and incurrence of a wide variety of "goods and "bads." Such models are often used to project the consequences of taking possible actions never before attempted.

In the final analysis, as the saying goes, "The proof of the pudding is in the eating." If the models are used over time by decision-makers in solving problems and if those solutions attain more of the "goods" and avoid more of the "bads" than was possible with alternative model constructs, they pass at least the minimal standards of the four tests of credibility.

The general system simulation approach, because it is eclectic with respect to philosophies; data and information sources and types; the use, nonuse, and delayed use of maximization, modeling techniques, and dimensions and because it can be used with relative ease to project the likely consequences of alternative policies, can be made an integral part of the decision-making process. Its eclecticism approaches the institutional eclecticism of decision-makers, thus facilitating their participation in application of the approach. With decision-maker participation throughout the process, including the application of the tests of coherence, correspondence, clarity, and workability, the formal models can become institutionalized directly into the decision structure as part of the investigative capacity. Hence, the credibility gap often observed among decision-makers, professional analysts, and modelers is greatly diminished.

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CHAPTER 2

VALUES AND POLICY CHOICES IN AGRICULTURAL DEVELOPMENT

George E. Rossmiller
Glenn L. Johnson

Introduction

In carrying out the planning and policy analysis function, it is important that decision-makers recognize that the agricultural sector interacts in a variety of ways with the rest of the economy. Conceptually, since our focus is on the agricultural sector, we can view agriculture as operating from within, and interacting with, an environment composed of the other sectors of the national economy. In this chapter we begin with a discussion of the relationships between the agricultural sector and the rest of the economy. We then turn to a discussion of the values important in development of the agricultural sector as an integrated part of the national economy.[1]

Agriculture and the National Economy

In most developing countries, agriculture is the largest single sector of the economy, both in terms of population and contributions to gross domestic product. In countries in the early stages of development, the agricultural sector may be so large and the nonagricultural sectors so small that subsistence farming is the predominant way of life in the national economy and the interactions between the agricultural sector and the nonagricultural economy are almost nonexistent. As urban and industrial sectors develop, however, and as migration from the farm to nonfarm sectors occurs, commercialization of agriculture and linkages between agriculture and other sectors of the economy begin to take shape.

Development of the nonagricultural sectors of an economy implies an increase in the relative proportion of nonagricultural population, although most developing countries have not gone above the 50 per cent mark. Farm-to-nonfarm migration, natural population growth, and increasing per capita incomes are factors requiring rapid commercialization of agriculture. Increases are also required in the capacity of the marketing, processing, storage, and transportation systems to handle increased volumes of agricultural commodities flowing from the farm to the urban areas. Shifts occurring in response to these demand factors at the farm level include pressures to increase agricultural production output and, because of a move from subsistence to commercialization and higher nonfarm incomes, a rapid adjustment in the enterprise mix.

The interactions between agriculture and the rest of the economy have the potential for becoming large and complex as development occurs. From the standpoint of the agricultural sector, potential contributions of an overall economy include (1) food; (2) employees for an expanding industry and urbanization process; (3) raw materials for industry; (4) export earnings and foreign exchange savings; (5) savings, government revenues, and newly formed capital to develop both the farm and nonfarm economies; (6) land for nonagricultural uses; (7) an environment favorable to quality life styles for farmers, rural residents, and urbanites seeking relaxation and recreation in a rural setting, and (8) a market for non-farm-produced production inputs and consumer goods and services.

Food

By far the major contribution of any agricultural sector to the rest of its national economy is the provision of food commodities. The demand for food in the aggregate is determined from two sources--population growth and per capita income levels. The rate of population growth can be used to directly approximate the rate of increase in demand for food due to population growth. The per capita income effect on food demand has both quantitative and qualitative aspects. As per capita incomes rise from extremely low levels, the major impact is an increase in the demand for more of the same kinds of agricultural commodities to satisfy a higher level of per capita consumption. As incomes increase further, a shift to preferred kinds of food commodities predominates. This shift is predictably from the staple food grains toward meat and dairy products, fruits, and vegetables.

Labor Supply for the Nonfarm Sectors

In developing economies off-farm migration and off-farm employment by members of farm households are normal phenomena. This movement can be regarded as a major contribution of the agricultural sector toward the development of the nonfarm sectors. Over time, this movement causes both a relative and an absolute decline in the portion of population engaged in agriculture. This implies that investments in rural education, vocational training, health, and sanitation are important, not only for the rural economy, but as off-farm migration increases, they become increasingly beneficial to the nonfarm sectors.

To assure that national interests are well served, while at the same time considering individual welfare, government policies and programs in agriculture and elsewhere should be attuned to influencing migration rates to keep them in line with the absorptive capacity for such labor in the nonfarm sectors. Migrants should not find themselves in a position of trading underemployment and low incomes in agriculture for unemployment and slum dwelling in urban areas. It is not only the overall rate of migration which is important here, but also migration rates by age, sex, and skill levels, to assure an orderly and rapid transition into available jobs in a developing nonfarm economy. Urban areas should not be required to suffer from having to provide services for jobless migrants, nor should rural areas suffer from loss of labor and transfer of rural wealth with migrants.

Raw Materials for an Expanding Industry

In many developing countries, a significant portion of the agricultural activity provides nonfood raw materials for domestic processing and use or export. Examples include fibers, such as cotton, wool, wood, hemp, sisal, copra, and silkworm cocoons; livestock by-products, such as hides and pig bristles; rubber; oils; and grains and other commodities for industrial production of alcohol and starches. In the early stages of economic development, most countries producing these types of products export them as raw materials. As the industrial base becomes established, opportunities arise for processing industries to supply both domestic and export markets with more highly processed forms of these basic raw materials.

Export Earnings and Foreign Exchange Savings

The agricultural sector in most developing economies can be an important source of foreign exchange, whether through exportation of domestically produced agricultural commodities and agriculturally based processed goods or through increased production of agricultural commodities for domestic use to substitute for imports. Governmental policies and programs to provide proper investments and incentives to direct agricultural production towards these objectives is required in most cases. Constant reassessment by government is necessary to insure that resource allocative efficiency, in accordance with comparative-advantage principles, is maintained to the greatest possible extent, given the need to satisfy domestic welfare objectives and equity criteria.

Capital Generation for Increased Rural and Urban Productivity

The agricultural sector is probably a greater source of capital for development of the farm and nonfarm economies than is commonly realized by governments or in lender and grantor circles because of the overlooked processes of (1) income transfer associated with migration and (2) the formation or production of specialized capital in agriculture by the person who "saves" and invests without utilizing the services of money markets. Nonagricultural development can be financed in part by surpluses forcibly extracted from agriculture through taxation, unfavorable terms of exchange from state trading organizations, or through investments by wealthy rural families. Even when none of these is occurring, income and capital transfers from farm to city take place. For example, migrants leaving the agricultural sector will usually take with them an inheritance claim on agricultural stock. In addition they may receive rents or payments based on the agricultural production from these claims on an annual basis. They also are likely to receive gifts of food from their rural relatives. Offsetting this outflow are the reverse flows of income from the migrants to the rural areas in the forms of gifts and grants to the families left behind.

In any event the net flow is likely to be from farm to the urban sectors. Government activity should also be taken into account in any determination of capital and income flows between agriculture and the rest of the economy. The net flow of taxes, government revenues, expenditures, subsidies, and other transfers between rural and urban sectors is one of fact and can be calculated, provided the data are available.

None of these calculations will include the nonmonetized contributions from agriculture to the nonfarm economy, including the value of human capital in off-farm migrants and the fact that labor and much of the capital used in the production of agricultural commodities for the nonfarm economy is very poorly paid. The agricultural sector traditionally has generated much of its own capital. Buildings, cultivated trees, livestock, and farm-produced equipment are but a few examples.

Land for Nonagricultural Use

With increased urbanization and industrialization, the demand for land for nonagricultural uses increases. Land is needed for new urban and suburban housing, industrial and commercial sites, streets, parks, reservoirs, and urban service areas. In addition, an increasing amount of land is used for roads and utilities. In land-scarce economies this means agricultural productivity must increase and/or high-cost land reclamation must be financed to replace converted land to maintain a given production level.

Quality of Life

A prosperous, productive, socially and politically stable agricultural sector, properly served by a well-functioning infrastructure, is an important asset for any nation. Not only is such an agricultural sector essential in providing for the nonfarm demands indicated above, but also for providing a favorable environment for work, leisure, living, and learning by farm people.

Agriculture as a Consumer of Nonfarm-Produced Goods and Services

In the category of demands placed upon the agricultural sector, not all goods, services, and human flows are from the farm to nonfarm destinations. As the balance of population tips away from the agricultural sector and/or agricultural exports gain in importance, the subsistence mode of agriculture gives way, through a commercialization process, to a market-oriented agriculture production activity. With this commercialization comes an increasing demand by agriculture for nonfarm-produced modern inputs, such as tools, machinery, chemicals, and commercial fertilizers, as well as nonfarm-generated capital and credit. Also, the increased cash incomes derived from the commercialization of agriculture allow farm household members to increase their effective demand for consumer goods and services produced in the nonfarm economy. This market link between agriculture and the rest of the economy creates opportunities for industrialization, commercialization, and the use of nonfarm capital and labor to satisfy the agricultural sector demand, thus further increasing the growth potential of the overall economy.

To insure an orderly and productive process of development and satisfaction of the nonagricultural demands placed on the agricultural sector with a minimum of attending hardships on individuals concerned, government must play a major role. To effectively carry out this role through planning and policy decision-making requires a body of normative and positive knowledge and concepts from which decision-makers can draw in making problem-solving prescriptions. We deal with the acquisition and use of positive knowledge in subsequent chapters. The process of building a stock of normative knowledge and developing an awareness of its implications must be done through interaction of decision-makers, analysts, and those who are affected by the decisions. Illustrative groupings of values or value constellations and relationships among values representing this normative knowledge in the development of an agricultural sector in a developing country are examined in the remainder of this chapter.

Value Constellations

Normative knowledge must be sought by investigators and decision-makers concerning broad national values, providing the philosophical environment and orientation for agricultural sector development. We will examine four possible national value constellations (combinations of instrumental and more basic values) which appear likely to be important for agricultural sector development in any developing country. These are the value constellations associated with (1) quantitatively and qualitatively improved food supplies, (2) realization of a higher quality of life in rural areas, (3) contributions from the agricultural sector to national economic development, and (4) administrative and political processes affecting the agricultural sector. Though values such as these are not likely to be explicitly stated by policy-makers or policy documents, a review of a country's policies, programs, and projects and interactions with policy-makers will undoubtedly lead to identification of value constellations similar to those stated as partial determinants, along with the necessary positive knowledge and prescriptive analysis, of the directions in which the agricultural sector should be developed.

Government attains values through plans and policies designed to achieve specific goals. A plan or policy strategy set can be formulated with mutually supportive programs and projects designed to achieve a set of goals which, if properly specified, will maximize the difference between *goods* and *bads* involved within and among such value constellations. The remainder of this chapter will examine the normative relationships involved in the four value constellations specified above to improve capacity to weigh one *good* against others where a *good* can be realized only by giving up other *goods* or increasing *bads*.

While the concepts in the following discussions generally apply to a wide range of agricultural sectors in developing countries, they derive from the collection and assimilation of normative information associated with the Michigan State University project in Korea. Thus, to the extent that the discussion is biased in any direction, it will tend to focus on a food-deficit country with scarce foreign exchange, limited agricultural resources--particularly land, a relatively well-developed and growing nonfarm economy, and a moderate population growth rate. The reader can easily make adjustments in the arguments to adapt them to countries with differing characteristics.

Relationships among Developmental Values for Agricultural Sectors

Values or concepts of goodness or badness of a condition, situation, or thing can be viewed as either instrumental or basic. Instrumental values are concepts of goodness or badness derived from more basic values. For example, the concept, "it is good for man to have money," may be based on the more basic value concept, "it is good for a man to be able to provide food and shelter for his family." More basic values contrast with instrumental values in that they are *goods* for the sake of which instrumental values are actualized. More basic values may ordinarily be actualized by a number of different instrumental values. In the above example, providing food and shelter for the man's family might be realized by means other than having money, such as through self-sufficiency or theft. Thus, it should be remembered that an instrumental value detached from the more basic value with which it is connected may very well be bad. For example, costs associated with agricultural production may be viewed as bad but may be recognized as necessary in order to attain a profit viewed as good. It should be recognized also in the example above that still more basic values, such as that of life itself, may make the values of food and shelter, which are more basic than money, into instrumental values.

The definition of instrumental and basic values takes into account those vertical relationships among values encountered when considering the value of a resource which is a means of attaining a more basic value. For example, fertilizer has value because it is a means of producing food grain, which has the more basic value of providing human nutrition. Similarly, vocational training has value because it is a means of increasing the production of more basic goods and services. At other times the relationships among values are horizontal, having to do with two or more values on essentially the same plane, such as the values of rice and barley, both of which provide human nutrition, but neither of which is a means of attaining the other. Because of these vertical and horizontal relationships among values, the following discussion deals with the ultimate or basic values sought by agricultural sector decision-makers and the values of different actions, programs, and policies which serve as means of attaining more ultimate or basic values.

In many circumstances means which have instrumental value can be used to attain several different, more basic values. In some circumstances the means available to society are relatively fixed. If such means are useful in attaining one of two or more basic values, their value is determined by what the economist calls the principle of opportunity cost; that is, the cost of using the means to attain a more basic value is the sacrificed attainment of the other values, which could have been secured with the same means.

In other circumstances a means which has instrumental value may be used to attain two or more different basic values simultaneously. In this case the attainment of the more basic values can be viewed as joint products of the means. In still other cases use of the means to attain one or more basic values may at the same time create consequences or conflicts precluding the attainment of other basic values. In such cases competition among values must be reconciled and conflicts resolved by choice of one or another of the values.

It must be pointed out that we are considering both monetary and nonmonetary values; and, thus, opportunity costs are nonmonetary as well as monetary. In the discussion of values to be presented in the remainder of this chapter, many references will be made to nonmonetary, as well as monetary, opportunity costs in considering alternative uses for scarce means.

Decision-makers have before them at any given time a number of values among which they can choose--both the basic values to be achieved and the means to obtain those basic values. These choices are crucial in setting the goals and targets to be attained in developing an agricultural sector within the context of a growing total economy. The following discussion considers both vertical and horizontal relationships among values important for agricultural sector development.

Improved Food Supplies

In considering the value constellation of improved food supplies, attention must be given to the value of a nation's food-producing resources and the costs of supplementing or diverting those resources, importing or exporting food, and changing food consumption. Costs, as a measure of value, are normative and nonmonetary, as well as monetary.

In a food-deficit country, two means are possible over time to balance food production with consumption. Figure 1 reveals diagrammatically how these two means are related to values, constraints, and other means of obtaining values in the food supply constellation. (In this figure and in the text which follows, numbers in brackets ({}) refer to the correspondingly numbered boxes in Figures 1, 2, and 3.)

On the one hand are policies designed to increase the supply of food {8}. A study of these diagrams reveals (1) the role played by the instrumental values as means in obtaining more basic values and (2) the importance of alternative uses for a means in determining their value or opportunity cost (nonmonetary as well as monetary) in attaining a given value.

On the other hand are policies designed to decrease the rate of population growth {1}. Population growth rates can be affected by population control {2} and through out-migration {3}. Investments in family planning programs {4} can provide information {7} and devices {6}. If a given percentage of growth rate is achievable with present investments in population control programs, an important question to ask is, What would lower this rate to an even more desirable target? Are there other means, such as economic incentives or penalties {5}, which would contribute to a lower rate at a lower cost? Housing size policies, a progressive educational head tax, or a regressive income tax deduction for larger families might be considered among these policy options.

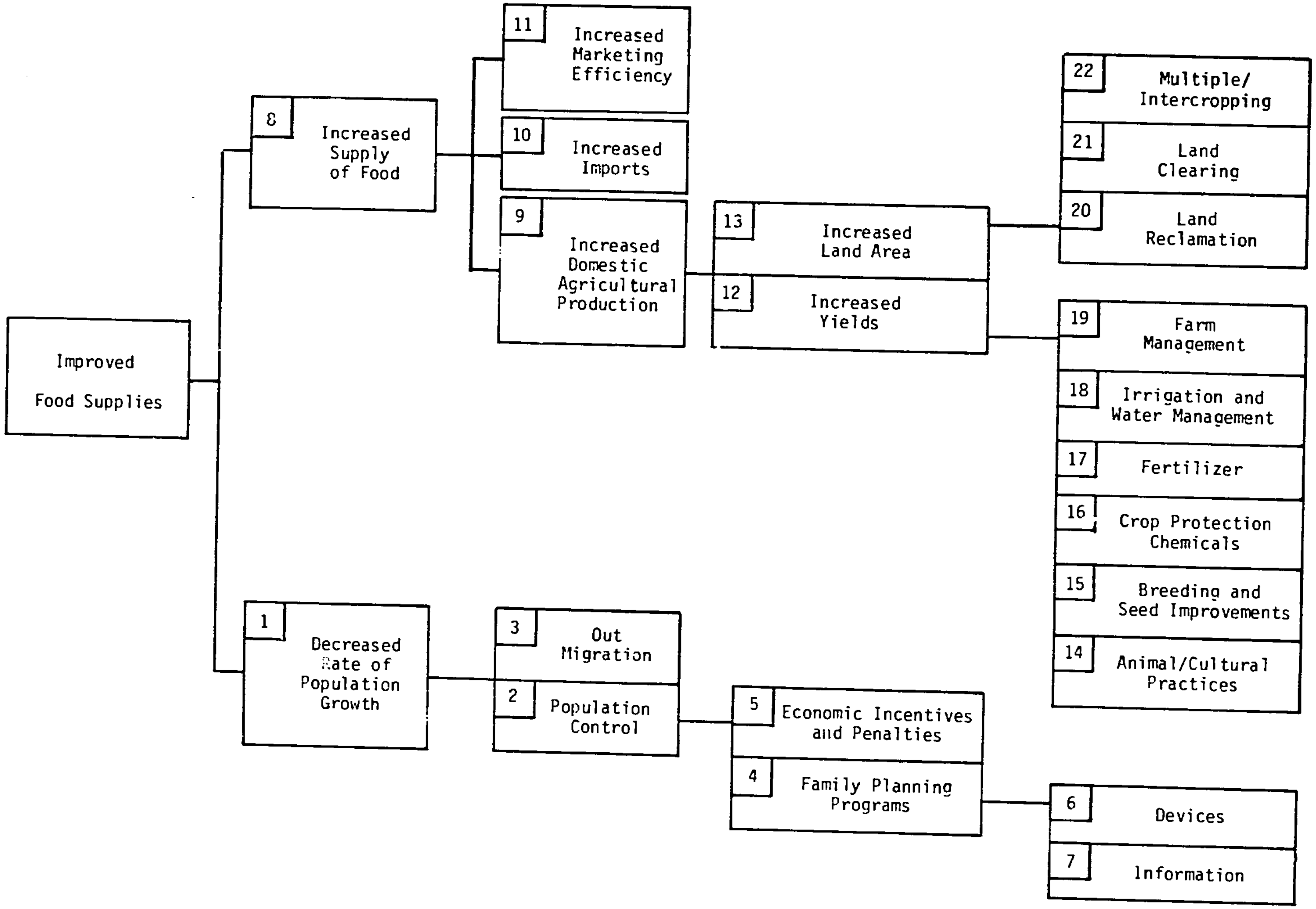

Figure 1. Values and Constraints Associated with Improved Food Supplies

Another means of obtaining a more favorable balance between population and food supply, as indicated above, is to increase the supply of food {8}. This can be done through increasing domestic food production {9}, through importation of food products {10}, and through increasing marketing efficiency {11}. Even with effective population control, most countries would probably need all these means to increase per capita food supply.

Imports, while contributing to the improvement of the population-food balance equation, have some potentially unfavorable consequences. One direct effect is the drain on scarce and valuable foreign exchange; another may be to depress domestic farmer prices and incomes through competition with domestic production. Both these "bads" may be offset through reallocation of released domestic resources from import-substitution agricultural production to export production (agricultural or industrial), or to industrial import substitution production, and through import policies designed to manage domestic prices at acceptable levels.

Domestic agricultural production {9} can be increased through increasing yields {12} on the existing land and livestock base or through increasing the land area {13} allocated to agriculture for the support of either food crop production or livestock. Increasing yields can be attained with new or existing technologies {12-19}. Improved cultural and animal care practices through new methods, techniques, and better management can improve yields at a relatively low cost. Selective breeding, development of new seed varieties, application of crop protection chemicals, use of proper amounts and kinds of fertilizer, and development of new irrigation and water management all can contribute to increased yields per unit of land area. In many cases these technologies are complementary and must be introduced as a package if they are to have value in increasing yields beyond those attainable when one or more components is missing. A broadly based, aggressive, and continuing agricultural research program, along with an effective delivery system to disseminate the information and research results to farmers, has substantial instrumental value.

The land area valuable for agricultural production can be increased through reclamation and land-clearing programs {20-21}. Land reclamation for agricultural purposes often can be justified only as part of more general multipurpose river or rural development projects. Another means of increasing effective land area is through extension of the techniques of multiple cropping and intercropping {22}. In addition to the potential for extension of agricultural land areas, there is always the question of the values and tradeoffs in using governmental and private investments in institutions and programs to reserve existing agricultural land for agricultural purposes.

The means to increase domestic agricultural production through increasing yields and increasing land area are many. Intensive analysis of the values to be gained from investments in research, development, and extension of these various means is required in each specific case, as is determination of the values sacrificed in attaining such more basic values.

Improved Rural Life

While emphasis in economic development of the agricultural sector in a developing country may be focused in the early stages on agricultural production, at some point in the process emphasis turns to values of the conditions, situations, and things which contribute to the quality of rural life. Figure 2 indicates diagrammatically how values are related in the value constellation contributing to improved quality of rural life. These include higher agricultural incomes {23}, control of income distributions {51}--both between agriculture and other sectors of the economy and within agriculture itself, expansion of rural infrastructure {54}, and preservation of personal freedom {67}. Since agriculture normally represents a large portion of the population and activity of the rural sector, increasing per capita agricultural incomes {23} is a direct means of upgrading the quality of rural life. Per capita incomes can be increased in turn by increasing the value of agricultural production {24}, thus providing more income to share among a given number of farmers. A decrease in the number of farmers {39} also would increase per capita incomes of those remaining. Decreasing costs per unit of output {36}, while maintaining prices, is a third means.

The value of agricultural production can be increased both by increasing agricultural prices {25} and by decreasing the volume of production {26}. Prices can be increased by increasing relative demand {27}, decreasing relative supply {29}, and increasing market efficiency {28}. Demand is increased through increases in population {30} (more mouths to feed), increases in per capita income {31} (people eat more and higher-valued food), and increased exports {32}. It is clear that

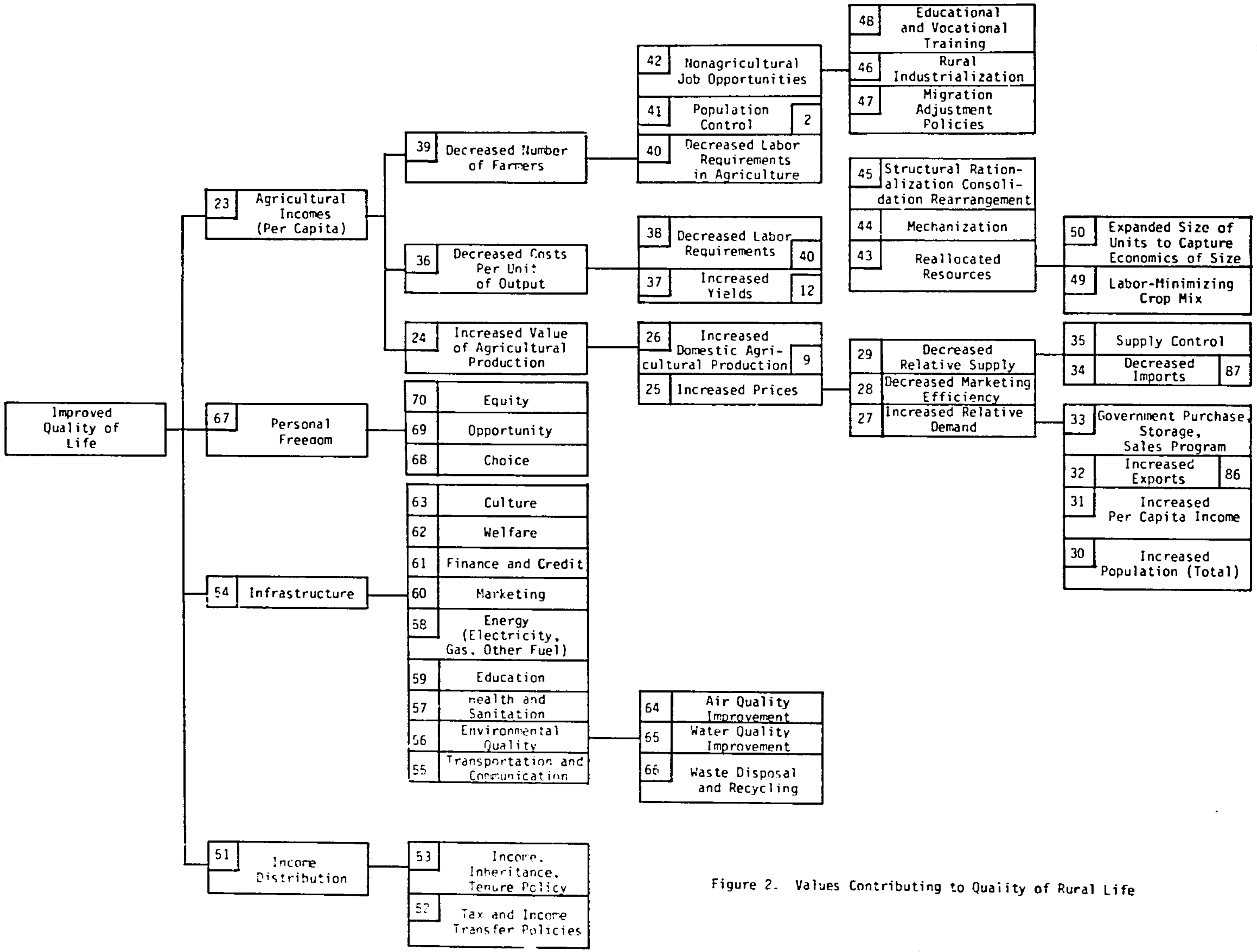

Figure 2. Values Contributing to Quality of Rural Life

there are many levels of instrumental values and, hence, opportunity costs or values, both monetary and nonmonetary. If the net effect of these factors is great enough to increase demand faster than supply, relative demand increases and puts upward pressure on prices.

Another means of increasing demand at least slightly and making it more uniform over time is through the operation of various government programs {33}. Such programs might include mechanisms, such as price supports and buffer stock operations, designed to stabilize prices over the crop year.

On the supply side in a food-deficit country, relative supply {29} can be affected by agricultural import policies. A decrease in imports {34} will decrease relative supply and increase domestic prices. Another possible valuable effect is to decrease the direct foreign exchange requirements. But other consequences of this kind of policy include effects on consumer prices, nutrition, and domestic resource allocation, which must be considered.

Other supply control measures {35} can be taken between commodities through pricing subsidies, licensing, or contracts to shift resources to produce the desired output mix. Analysis is necessary to determine consequences of specific policy actions. In any case, one of the most effective means of increasing prices from the supply side in a food-deficit country is through import restraints, with selective supplemental measures on an individual commodity basis.

Measures to increase marketing efficiency {28} also can have the value of increasing producer prices, to the extent that market savings are passed on to producers, and of lowering food prices to consumers, to the extent that savings are passed on to consumers. Adequate facilities for bringing buyers, sellers, and products together; facilities for storage, transportation, and communication; and processing facilities are necessary to improve market efficiency.

Another means of increasing the value of agricultural production is to increase production, as measured by domestic agricultural product {26}. Measures to accomplish this are indicated under {9} in Figure 1.[2] Increased agricultural production must receive major consideration because it contributes to attainment of values concerning food, quality of life, and general economic development.

Per capita agricultural incomes can also be increased by decreasing the number of farmers {38}. For this to be accomplished, the agricultural sector must be restructured in such a way that fewer farmers are needed {40} in total and seasonal peaks in labor requirements are minimized. In addition, the farmers who are willing and able to leave agriculture must have alternative employment opportunities in the nonfarm economy {42}. A somewhat less significant force contributing to a decline in the number of farmers is general population control {41}, which affects both growth and employment.

Labor requirements in agriculture can be reduced in several ways. These may include mechanization {44}, land rearrangement and consolidation {45}, reallocation of resources {43} to produce a labor-minimizing crop mix {49}, and reducing the number and increasing the size of individual farms to make more efficient use of existing labor and other resources {50}. Pressures for these kinds of adjustments will build as labor supply becomes less plentiful in rural areas and as agricultural labor wage rates rise. Some adjustments to a shortage of labor may cost relatively little. Others, such as full-scale mechanization programs, may require considerable cash outlays from farmers. As labor flows out of agriculture and as agriculture becomes more commercialized in input and output markets, capital requirements will multiply and credit needs will become acute. Delivery of adequate and timely credit at reasonable cost to the agricultural sector is a major challenge in most developing countries.

For those people who leave agriculture, a number of means of providing nonagricultural job opportunities {42} will be necessary. To do so, growth in urban areas and urban industrial and service employment is necessary. In order to pull enough labor from rural areas to man the growing urban industrial complex, migration adjustment policies {46}, possibly in the form of migration and resettlement allowances may be used. If the rate of off-farm migration is higher than the absorption capacity of the urban industrial complex for labor, these kinds of programs would have a negative value. Urban areas may suffer from having to provide services for jobless migrants, and rural areas may suffer from loss of labor and transfer of rural wealth with those same migrants. A population dispersion policy with rural industrialization {47} would slow the rural-to-urban migration rate. In any case, as the total economy develops, the compulsory basic education age level is likely to increase and additional vocational training and retraining investments {59} will usually be required to provide the industrial labor market with laborers of necessary skill and education. These skills are most appropriately provided in rural areas, and governments should be willing to use investment transfers to upgrade the rural educational resources.

The third method of increasing per capita agricultural income is to decrease the cost per unit of output {36}; thus, increasing the net return with a given set of product prices. This can be accomplished by increasing the yields per unit of land area {37} and/or per unit of labor input {38}. Both land-saving and labor-saving technologies can contribute to this objective. Labor-saving devices can greatly increase the quality of rural life by reducing the drudgery and the amount of hard, slow-paced labor required.

Another means of improving the quality of rural life is to influence the distribution of income {51} toward increased equity, both within the agricultural sector and between the agricultural and nonagricultural sectors. It should be noted that many policies, particularly price and income policies, often tend to widen rather than close the gaps in the distribution of income. This is a general problem faced by most countries in formulating policies dealing with agriculture. Tax and transfer policies {52}, including income and inheritance taxes and tenure policies {53}, can be used to bring about the desired inter- and intra-agricultural income distribution.

One can argue with a great deal of justification that policies and investments affecting the environment within which agriculture operates contribute more to achievement of the national goals by agriculture than many of the policies and investments which could be directed specifically to the agricultural sector itself. As the ratio of nonfarm to farm population increases and agriculture becomes more commercialized, infrastructural investments {54} supporting agriculture and its urban markets must increase. To increase the effectiveness of production and marketing of agricultural products, infrastructural investments in transportation and communication {55}, rural electrification {58}, marketing {60}, and credit {61} institutions and systems become crucial. In addition, as farmers and rural people see many of the advantages afforded their urban cousins, they also become more interested in contributing to their own personal well-being and to that of their children through better medical, health, and sanitation facilities {57}; cultural activities {63}; educational opportunities {59}; environmental quality {56}; and investment in their general welfare {62}. Some of the infrastructural improvements indicated are not normally considered in analyses of the agricultural sector, in part because they fall outside the scope of responsibility of the agricultural ministry in most countries.

While it is difficult to treat the subject of personal freedom {67} empirically as a contributing component to the quality of rural life, it must be an implicit consideration in the formulation of policies and programs designed to develop the agricultural sector. Such policies and programs should be based upon consideration of their consequences upon rural people's freedom of choice {68}, their freedom and level of opportunity {69}, and equity {70}. Further, farm management and marketing decisions are more likely to reflect better use of resources, if farmers and marketers responding to their environment decide what actions they will take, rather than being directed in their actions.

Agricultural Contributions to General Economic Development

In addition to supplying food, many other valuable contributions are expected in most nations from agricultural sectors for development of the nonfarm economy. Figure 3 diagrams some of the interactions among valued contributions and means of obtaining them. General economic and social development can be enhanced through increases in gross national product (GNP) {71}, improved urban quality of life {78}, and a favorable balance of payment situation {85}. The agricultural sector can contribute to these components in a number of ways.

Total GNP {71} can be increased through increasing agricultural GNP or by increasing the value of agricultural production {72}. One means for increasing the value of agricultural production has already been diagrammed in Figure 1, starting with block {24}. The other means for increasing total GNP is to increase nonagricultural GNP {73}.

Agriculture can contribute to the increase in nonagricultural GNP through providing agricultural production inputs into nonagricultural industries {75}, such as providing the raw materials for agribusiness processing firms, such as canning companies, meat processing firms, and milk and dairy product processing plants. Another means is through supplying excess labor capacity from rural areas to urban industries as urban industrial jobs become available {76}. Still another way is through increasing the use of purchased inputs {77} in agriculture, provided these inputs are produced in the domestic, nonfarm economy. Finally, with the transfer of people from rural to urban areas, it can be expected that some wealth will transfer as a part of the migration

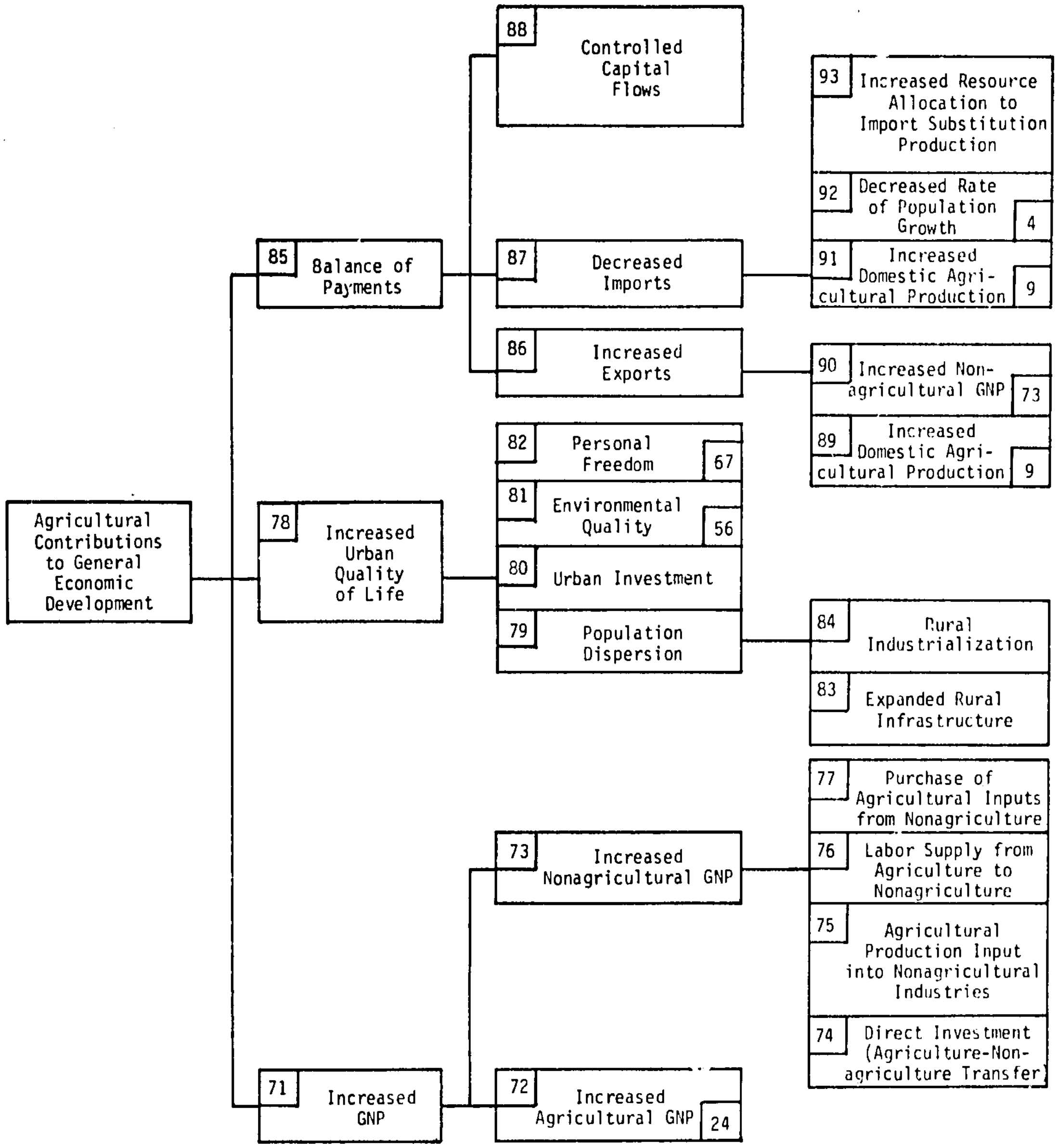

Figure 3. Agricultural Contributions to General Economic Development

process, including proceeds from the sale of farms or the inherited share of farm businesses. These assets from the agricultural sector can be provided as direct investments {74} to the urban sector to increase industrial capacity to produce goods and services and nonfarm GNP.

There are a number of means by which urban quality of life {78} can be enhanced, such as increasing urban investments in infrastructure {80}, investments in environmental quality {81}, and increases in the degree of personal freedom allowed {82}. As urban centers become larger, more concentrated, and congested, population dispersion policies {79} and rural industrialization {84} become necessary for potential rural-to-urban migrators to find job opportunities without migrating. Another prerequisite for population dispersion and probably even for rural industrialization is the expansion of the rural infrastructure {83} already discussed. Urban environmental quality can be enhanced through population and industrial dispersion policies which provide for air quality improvement {64} and water quality improvement {65}.

A great deal of attention should be focused on the problem of waste disposal and recycling in both rural and urban areas {66}. Another means by which the agricultural sector contributes to general social and economic development is through helping maintain an acceptable balance of payments {85} in a nation's economic relationships with the rest of the world. The three main components of the balance of payments are exports, imports, and long-term capital flows. Long-term capital flows {88} must be rationalized over time to contribute to balance of payment stabilization. On the trade side there are two ways to avert a balance of payment deficit--increased exports {86} and decreased imports {87}.

In terms of the agricultural sector, exports can be increased through increasing domestic agricultural production. Agriculture can contribute to increased exports also through the means discussed above in increasing nonagricultural GNP, again coupled with policies promoting exportable production {90}.

Other means of stabilizing the balance of payments is through a decrease in imports. Imports can be decreased, or at least increased, at a slower rate by policies which decrease the rate of population growth {92}. A more effective way might be through increased domestic agricultural production {91}, stressing policies which contribute to increased production of import substitution products. The same argument can be made for increasing nonagricultural GNP by providing resources to the nonfarm economy for import substitution production {93}. This assumes that the increase in export-plus-import substitution production is greater than the increased import-plus-export diversion, due to larger per capita incomes and the marginal propensities to consume and import.

Administrative and Political Considerations

A prerequisite to the planning, policy formulation, and program development necessary to attain the values for national agricultural sector development is governmental organization and administrative structure at all levels flexible and responsive to the needs of rural and urban citizens. Choices must be made, complementarities exploited, conflicts resolved, and policies executed in a manner designed to achieve goals with the physical, human, technical, and institutional resources available, a minimum of adverse economic and social consequences, and both short-run needs and long-run requirements considered. Values in government administrative capacity are necessarily political.

Effective administration of agricultural development policies, programs, and projects involves, among other considerations, the values of

(1) Coordination of decision-making and planning responsibility, with administrative control of persons and agencies executing the decisions

(2) Reliable sources of information on the performance of those executing the decisions and of the phenomena being controlled

(3) Sufficient insulation from the political arena of decisions and administration for technical and economic agricultural systems to permit such systems to function without political disruption

(4) Provision for technical agricultural competence to influence the planning and administrative processes at all levels

(5) Analytical capacity to take into account the full range of relevant information, using the full range of available techniques, as appropriate and uncontrolled by administrative and political personnel

Policy Choices

In the discussion and figures of this chapter the reader will note the emphasis on instrumental values connected with agriculture sector development in attaining the indicated basic values. Much less completely sketched are other values connected more broadly with rural development, particularly in the diagram and discussion pertaining to the value of increased quality of rural life. Additional instrumental values as means of attaining more basic values along these lines could be included, but for our purposes here they would unduly complicate the discussion.

The job of the planner and the policy decision-maker is to determine the weighting of the values to be attained, both among and within the value constellations considered. More weight may be given to those instrumental values or means which contribute to attainment of a larger array of more basic values and less weight to those producing fewer "goods" or which produce more "bads" as a by-product of the "goods." Establishment of the weights requires a synthesis of the kinds of normative knowledge described in this chapter and positive knowledge describing the system under consideration and how it works; in this case, the agriculture sector. With this synthesis, the decision-maker can proceed to the establishment of realistic and relevant goals and prescribe the right actions required to achieve those goals.

In making the choice decisions among the complex of values to be attained and avoided, the decision-maker must be cognizant of the time and adjustment path, as well as the ultimate consequences of his actions. Some policy choices, such as land reclamation or population control, may require large initial investments, with long delays before the benefits are realized. Impacts of other policy actions, such as price controls or embargoes are immediate. Some policy choices may have short-run benefits without lasting value if they treat only the symptoms of disequilibrium resulting from fundamental structural change in the economy. To make the appropriate choices and determine the right actions, decision-makers require a continuous analytical input into the decision process.

FOOTNOTES

[1] This chapter draws heavily on concepts found in [1], particularly Chapter 5.

[2] Numbers in lower right corner of blocks in Figures 1, 2, and 3 refer to those blocks elsewhere in the figures and indicate linkages necessary to complete the line of reasoning.

REFERENCE

[1] Rossmiller, George E., *et al.* Korean Agricultural Sector Analysis and Recommended Strategies, 1971-1985. Seoul and East Lansing: Agricultural Economics Research Institute, Ministry of Agriculture and Forestry, Republic of Korea; Department of Agricultural Economics, Michigan State University; 1972.

CHAPTER 3

THE THEORY AND PRACTICE OF MODEL-BUILDING AND SIMULATION

Thomas J. Manetsch

Introduction

A major purpose of this chapter is to provide a specific, but relatively nontechnical, description of the rather involved processes which lead to models which can be used in addressing sets of problems in a subject-matter modeling context or specific problems in a problem-solving modeling context. The material discussed should be of use to at least three distinct groups of people:

(1) Decision-makers who need some understanding of these processes to make informed use of models as aids to decision-making

(2) Nontechnical administrators who are related in some way to a system simulation team responsible for developing and maintaining subject-matter and decision-oriented problem-solving models

(3) Members or potential members of a system simulation team who need a nontechnical orientation to the model-building process

The model-building process is more-or-less general in nature. That is, the steps involved in model-building are likely to be about the same whether the model is at the enterprise level to aid a farmer in making planting decision, at the subsector level to aid government in arriving at decisions for regulating commodity prices, or at the sector level, where a myriad of decisions influence many important aspects of rural and national life. The discussion that follows, therefore, has applicability to a range of model-building situations.

Decision-making at various levels in agricultural development is always subject to error. Uncertainty with respect to weather, prices, basic information describing the nature of the system being managed, etc., guarantees that we cannot always make the "right" or "best" decisions. Good models aid in decision-making by improving the quality of decisions and increasing the probability of decisions leading to "right" actions--but that is all they can do. A key qualification in this last statement is that the model in question be a "good" model. The discussion that follows will help the reader to know a "good" model when he sees one.

There are three major places where models can go wrong. The first is the "problem definition" level. At this stage a model must be addressing the right problem or set of problems. It must accept the right variables as policy inputs and produce the right variables for enabling decision-makers to evaluate alternative policies. The second major test of a "good" model is the quality of its mathematical structure as an approximation of that part of the real world of interest. In most practical decision-making situations, the system is complicated enough mathematically to require that it be solved by computer. This gives rise to a computer model that approximates the mathematical model that approximates the real world. The third test of a "good" model, then, is how well the computer model approximates the mathematical model.

The Model-Building Process

In this section we look at key aspects of problem definition, which is the logical starting point for any modeling activity. We then survey model-building approaches and describe the process whereby large subject-matter or decision-oriented models are built from components using the important "building block" approach. This section concludes with a discussion of some coarse checks for validity of the mathematical model with respect to its internal logical consistency.

Problem Definition

So-called "problem definition," as part of model-building, is the process whereby we specify precisely what a model must contain and do in order to meaningfully address the important policy issues under consideration, whether in a problem set or in a specific problem context. In the particular real-world setting of interest, much has been written about this important issue [3, 5, 12, 13]; and we will only present an overview of key points. It is very important to understand at the outset that there is more to "problem definition" in a practical, decision-making situation than is described here. Formal models are but one input to the decision-making process; and "problem definition," in a larger sense, must lay the groundwork for all the activities needed to arrive at sound decisions and their implementation in the real world.

In order to lay a foundation for a model that will meaningfully address decision issues, "problem definition" must include the following:

(a) Assessment of the various goals that are to be satisfied as a result of the decisions to be taken (stated in other terms, to specifically determine the objectives sought; i.e., increases in farm income, equitable income distribution by particular regions and social classes, etc.)

(b) Explicit definition of the boundaries of the system being managed (Loosely speaking, this determines the range of factors that must be considered in arriving at decisions.)

(c) Determination of the various, specific criteria the model should produce in order to enable decision-makers to properly evaluate various alternative courses of action. Examples of such criteria include per capita incomes (perhaps by specific regions and/or social classes), contribution to GNP, foreign exchange earnings (or deficits), costs of government programs, measures of human nutrition and costs or revenues to government as a result of various policy actions. Complete specification of these criteria also requires definition of the units of measurement desired and the time frequency required--yearly, quarterly, etc.

(d) Explicit and exhaustive specification of the decision variables which can be exercised in attaining the goals sought

Good problem definition is one of the most challenging phases of model-building. It requires the accumulation of much information; the analysis and synthesis of information to isolate that of significance; and, most importantly, close cooperation and interaction between decision-makers and model-builders.

Model Types

A good "problem definition" will provide a framework within which an appropriate model can be developed. Several types of models can be built; and, again, a good "problem definition" can help in determining which type is best for the situation at hand.

Models can be classified according to the view they take of the real world: microscopic or macroscopic. Microscopic models take a very detailed view of reality and represent, explicitly, individual entities moving through, or being processed by, the system. For example, a detailed model of the operation of a grain storage system would represent each individual shipment of grain as it was loaded or unloaded at the storage facility. A macroscopic (or aggregative) model, on the other hand, deals with aggregative flows of goods or services; for example, aggregated birth and death rates in a population or total production of a commodity in a geographical region. A good "problem definition" will help us decide which type of model to build. Some problems require a microscopic point of view; for others, a macroscopic model is clearly more appropriate.

A second important way to classify models is by whether or not they represent dynamic phenomena in the real world. A good test to determine whether a given system or situation is dynamic or not is to pose the question, "Will actions taken today influence the future in some ways it is important to assess?" If the answer to this question is "yes," we are dealing with a dynamic system or situation. Clearly, development is a dynamic process; and in many areas we need dynamic models to adequately deal with development problems. Dynamic models are usually constructed using differential or difference equations[1] because such equations are able to project into the future the approximate consequences of decisions taken at the present time. Models constructed using differential or difference equations, therefore, are useful in helping evaluate some of the future consequences that are likely from alternative courses of action taken today. The study of these kinds of equations and their real-world ications is an important part of the body of knowledge called "systems theory."

A nondynamic model is a static model. Static models are incapable of providing information about the future consequences of current decisions. They are constructed using algebraic equations (equations which do not contain past values or rates of change of system variables). Static models too can be useful in addressing decision problems in agricultural development. For example, a static model may be able to tell a farmer how many acres of various crops he should produce this year, given particular assumptions about prices and yields per acre.

A third important way of classifying models is according to whether they are deterministic or stochastic (random). A stochastic model contains random elements which cloud model outcomes with uncertainty, while deterministic models do not. Deterministic models are appropriate when the effect of stochastic elements are small or negligible; i.e., deterministic models do an excellent job of predicting where in space the moon and planets will be at some future time. In most development problems, however, randomness in variables, such as prices and weather, has a substantial impact on the outcomes of interest in decision-making. Deterministic models are sometimes used, even in these cases, to tell what is likely to happen if all random factors take on their average values.

Stochastic models approximate the impacts of random factors and provide decision-makers with some idea of the range of outcomes that are possible from a particular decision, given the random factors that are present in the given situation. In order to do this, models are operated repetitively in a so-called "Monte Carlo" mode. In each "Monte Carlo" run of the model, the random factors involved are allowed to take on a different set of values that are consistent with the randomness inherent in the real world. The results of Monte Carlo analysis with a stochastic model might be something like the following (oversimplified) example.

(1) Decision Alternatives	(2) Expected Outcome	(3) Range of Outcomes
	(Benefit in Appropriate Units)	
A	2,500	1,900-3,000
B	3,600	2,800-4,200

Table 1. Typical Results of Monte Carlo Analysis

These results are interpreted as follows. The average or expected benefit from decision alternative A is likely to be 2,500 units (thousands of dollars, etc.), and the probability is (say .95[2]) that the actual benefit will be between 1,900 and 3,000 units. A similar interpretation applies to decision alternative B. In this case alternative B is likely to be better than A, but there is some (small) chance that A may turn out better than B. Monte Carlo analysis can easily be extended to the situation where decisions affect a number of criteria which must be evaluated. While operating stochastic models in a Monte Carlo mode, as above, provides additional information for decision-makers, model operating costs are increased. It simply takes more computer time to assess the range of outcomes that are possible when random influences are included in the model.

Another major model classification is that of optimizing versus nonoptimizing. An optimizing model gives a decision-maker information describing the courses of action that will lead to the optimization of a particular criterion. Most optimizing models can do this subject to constraints which ensure that other criteria are at prescribed levels or within prescribed bounds. Nonoptimizing models simply indicate what outcomes, as measured by various criteria, are likely to result from various alternative decisions.

Several other ways to classify models are possible, but they are not of central importance to our discussion here. Clearly the choice of model type is important, as it greatly affects model capability, cost of model development, and cost of model operation. In light of the substantial model development and operating costs that are possible in large applications, these should be enlightened decisions. The following generalities can assist in this:

(1) Dynamic models are usually more costly to develop than static models. However, they usually provide decision-makers with significantly more useful information

(2) Micro models are not necessarily cheaper to build than macro models (even though much more limited in scope) because they often contain elaborate detail

(3) Stochastic models usually are not much more expensive to build than deterministic models, but they are much more expensive to operate

(4) Optimizing models are usually much more expensive to operate than nonoptimizing models

(5) The cost of operating a nonoptimizing model usually goes up directly with the size of the model (as measured by the number of variables contained in the model)--double the size, double the operating cost

(6) The cost of operating optimizing models tends to go up much faster than the model size--double the model size, (perhaps) quadruple the operating cost

(7) Model development costs tend to go up much faster than the model size--double the size, (perhaps) quadruple the cost

Obviously, important decisions are necessary regarding the type of model to construct. On the basis of the four, two-way classifications discussed (macro-micro, static-dynamic, deterministic-stochastic, optimizing-nonoptimizing), there are potentially 16 distinct model types that can be constructed. Careful thought and selection at this point can pay significant dividends in terms of reduced model costs and, ultimately, in model effectiveness as an aid to decision-making.

Modeling Approaches

With the broad outlines of the system model established as a result of sound problem definition and given selection of the most appropriate model type, two major approaches to model-building can be employed singly or in combination. These are the so-called "black box" and "structural" approaches. Essentially the "black box" approach seeks to identify a system model from data describing the past behavior of the real-world system. Through various statistical and mathematical techniques, a model is derived which in some sense is a "best" fit to the historical data. This approach has developed independently in the social and physical sciences. The field of "econometrics" [9] is representative of the social science stream of development, while much of the work done in "system identification" [8] in various areas of engineering employs "black box" methods. This method has been used extensively in agricultural development, for example, to specify mathematically how producer supply and consumer demand [9] are likely to change in response to factors such as market prices and income levels.

The "structural" approach to model-building attempts to represent or simulate the detailed system structure that causes the total system to behave as it does. This approach decomposes a system into its component parts, builds mathematical models that approximate the behavior of those component parts, then interconnects the component models to obtain a model of the overall system. For example, a structural model of a domestic commodity market would develop component models that represent the behavior of producers, middlemen, and consumers. These component models might contain considerable detail in representing crop production and transportation processes and decisions that manage stock levels and determine commodity purchases and sales. Many, if not most, large-scale decision models are developed using this approach aided by the "black box" approach to fill in certain parts of the structure [7, 12].

These two basic means of constructing system models should be regarded as complementary--each possessing unique capabilities and limitations. For example, the "black box" approach is based on past observations from an existing system and cannot be used in designing a new system that does not yet exist. On the other hand, in certain management problems the task at hand is to manage an existing system whose inner workings are unknowable. In this case, the "black box" approach is the only recourse. In summary then, the nature of the system will determine which of the approaches should be applied or in what combination both should be applied. Clearly, use of the two approaches together brings more information to bear on the modeling problem and will generally lead to better models than either approach alone.

Definition of Model Components

As implied above, most models of complex, real-world phenomena are best broken down into a number of interconnected submodels or components.

There are several advantages in doing this. In the first place, this can lead to a natural division of effort within a model-building team. People within the team can be assigned a component they are well equipped to deal with by virtue of training and experience. Further, it is usually more economical to develop and test a large model component by component, as large models are normally cumbersome and difficult to develop. A final advantage of building models from so-called "building blocks" is that in some cases it is possible to use previously developed components for parts of the total model structure. Examples of model components in an agricultural sector model would be agricultural production and consumption (perhaps disaggregated by regions, farm size, etc.), private marketing and transportation, government marketing and transportation, and urban consumption (perhaps disaggregated by region and/or income class).

With its advantages, this "building block" notion is not without its problems and must be carefully implemented. A key step is the appropriate definition of the model components. If components are inappropriately defined, a simulation team will find itself working at cross purposes and wasting considerable time and resources. Adherence to several basic principles will help in the definition of "appropriate" model components and reduce the likelihood of wasted time and resources in model-building. Following are helpful principles:

(1) The boundaries of each component must be carefully defined in terms of the input variables it must receive and the output variables it must produce. These variables must have common units of measure in each component and timing must be compatible among components (monthly, quarterly, etc.)

(2) Components must be defined so that all variables required as inputs are either produced as outputs from other components or specified externally or exogenously (for example, world commodity price projections would be external or exogenous variables for a national agricultural sector model)

(3) Model components must be defined so that the structure of one component is independent (or nearly so) of the structure of other model components. If this were not the case (and it isn't automatically the case), the modeler of each component would have a "moving target" that depended upon what other model-builders were doing. For example, in a model of a farm-firm-household, it would be inappropriate to have production decision, consumption decision, and investment decision components, since all these decisions are interrelated. It would, however, be appropriate to have a "decision" component that embraced all these areas

Developing Component Models

Given that model components are well defined and input and output variables are explicitly specified, the next question is how the component models are explicitly developed in terms of mathematical equations. While model-building is an art acquired by experience (the art of creatively describing real-world phenomena by mathematical abstractions), there is a backlog of previously developed model "archetypes" upon which the model-builder can draw. The model archetype appropriate in a given modeling situation is, of course, determined by the type of model that is needed to address the relevant real-world problems. We will, therefore, discuss model archetypes in association with the model type or types to which they pertain.

One model archetype is fundamental in importance because it applies to most dynamic models. This is the so-called "conservation of flow" model. This archetype is simply a mathematical statement of the principle that matter and energy cannot be created or destroyed. Examples of applications of this model include inventory-like processes--any difference between flow in and flow out is made up by a change in the level of stock stored in the "inventory." Specific applications include modeling commodity storages at the farm, marketing, and consumption levels; modeling cash flows and cash balance (the "inventory"); and modeling populations of people, animals, etc. (the number of people, cattle, etc., in a given age/sex class is an "inventory" level).

Another important model archetype that is applicable for many dynamic models is the "cybernetic" model [6]. Cybernetics is the science of control, and the cybernetic model applies whenever the deviation between the desired and actual value of a quantity is used to change the quantity in the desired direction. There are many applications of this principle in agricultural sector models. For example, subsistence farmers, to some extent, base their commodity sales decisions upon the difference between their current commodity stock levels and the level desired to feed the farm family until the next harvest period. Or, in implementing a price regulation program, a government may purchase or sell in the domestic market, depending upon whether the market price is below or above the desired or target price. (Further, the amount of purchase or sale is usually in proportion to the difference between actual and target price.) The cybernetic model is useful in developing models of such phenomena when they occur or when their occurrence is desired in the real world. There are many important applications of "cybernetic" or "control" theory in agricultural sector modeling, and the "complete" model-builder should be well versed in this field.

Other model archetypes useful in structuring dynamic models are two classes of time delays. The first is the so-called discrete or "pure" time delay [13]. These delays generally are used in micro-level models to mathematically represent the time lags inherent in human decision-making, transporting a unit of goods from one point to another, providing a service, producing a unit of output, etc. The discrete delay is also used in the development of models which simulate the age and sex distribution of populations (people, animals, trees, etc.) over time.

The second important class of delay is the "distributed" delay (also called the "continuous" delay). This delay has proven very useful in developing mathematical models of aggregative (macroscopic) delay processes. It has been used, for example, in modeling aggregate lags in production, consumption, transportation, and capital formation. In other words this model archetype is useful in simulating lags in aggregate variables which are streams of goods and services originating from many sources at the micro level. This delay concept has also been used in population models of trees and animals, where it is important in simulating output over time to keep track of the number of entities in the population which are at various levels of maturity. Population models using the discrete delay keep track of the numbers of population entities according to chronological age, which sometimes is not as useful in predicting productivity. Distributed delays are represented mathematically by differential equations, while difference equations are used to describe discrete delays. Systems modelers should be well acquainted with these types of equations, their real-world significance, solutions, and solution properties.

We have been discussing model archetypes which are useful in describing dynamic systems. Another in this category is the so-called "queueing" model [17]. The queueing model is used frequently to represent stochastic microscopic processes which are dynamic in nature. A basic queueing model is composed of a "service station" which processes individual system entities with a random service time and a "waiting line" of entities waiting to be served. An application of a queueing model might be the off-loading of grain at an elevator or port. In this case the "service station" is the off-loading equipment and the "waiting line" is the group of trucks or ships waiting to be off-loaded. Queueing models are useful in designing efficient systems which have the above characteristics.

Another type of model which may be used in some cases to represent dynamic systems is the so-called "simultaneous equation" model [9]. This model is also used in some cases to represent static systems. Such models result from application of the "black box" approach in that they are derived from past data from the real world. In the case of dynamic simultaneous equation models, a set of difference equations is determined which results in a "best" fit to the historical data from the real world. Econometric methods are important here, and the model-building team should include one or more persons with expertise in this area.

Model archetypes which are normally used in the construction of static models are also important. One such archetype is the "input-output" model [2]. The input-output model has been used extensively to study interactions that take place among the sectors of an economy (or the subsectors of an agricultural sector). With such a model it is possible to determine the totality of changes in flows of goods and services in an economy (or sector of an economy) that must take place in order to sustain particular development goals; for example, to expand output of certain commodities. The basic input-output model, as such, does not model the process whereby the system moves from one operating condition[3] (equilibrium) to another and, therefore, offers little insight into how to move the system behavior in desired directions. It does, however, provide useful information on the feasibility and characteristics of different operating conditions. With additional modeling effort, a basic input-output model can be made dynamic and thereby to provide information for determining investment and other policies which can move the system to some desired future operating condition.

The linear program [17] is another model archetype that is often used to address static questions. The linear program is an optimizing model that is frequently used to indicate to decision-makers the mix of input resources that will optimize some single criterion of interest (production cost, net profit, etc.). This model has been used extensively at the farm level to guide the allocation of land, labor, and capital to various production acitivities subject to a variety of constraints on inputs and outputs. It has also been used in agricultural sector models (including the Korean model) to approximate the way farmers, in the aggregate, respond to changes in input and output prices, interest rates, and other variables that are influenced by policy actions. Like the input-output model, the linear programming model can also be made dynamic through so-called "recursive linear programming". Members of the model-building team should be skilled in the use of both input-output and linear programming models.

The available model archetypes discussed above can be useful in structuring components of larger models. In smaller applications, however, the component may be the total model used in decision-making. Models and model components may include a number of the model archetypes. Attention is now turned to other raw material that is often useful in structuring component models. In particular, the contributions of disciplines such as economics, biology, physical science, and sociology will be discussed.

Role of Disciplinary Inputs in Component Modeling

The contributions of economic theory to the construction of components for agricultural models are quite extensive. Only a brief overview will be provided here. In many decision-oriented models we are faced with the problem of modeling the likely consequences of policy actions upon a system which contains a number of private decision-makers having some freedom to behave autonomously. Economic theory can provide us with information useful in developing models which can approximate the behavior of these private decision-makers in response to policy actions. Models constructed on the basis of theory must always be tested for credibility, but the theory often provides a useful starting point.

Economic theory has provided a useful framework for modeling farm-level decision-making in production, consumption, and investment. While much more work remains in this area, the farm-level linear programming model cited above is one application to date. In certain applications, such as the Korean grain management model (see Chapter 16), it is important to be able to approximately simulate the decision-making of private middlemen as they buy, sell, and manage their stock levels in response to prices, interest rates, and other relevant variables. The grain management model has used economic theory extensively in modeling this kind of behavior; but, again, much more work is needed in this area. A third major area in which economic theory can contribute to model-building is in modeling consumer demand as it responds to changes in factors, such as commodity prices and per capita income levels.

Another discipline important in structuring agricultural models is biology. Since many of the processes we seek to manage effectively in agricultural development are biological in nature, it follows that we must have reliable models of these important biological processes. Of particular importance are models that describe effects of different input allocations on the outputs of annual and perennial crops and various livestock. Again, progress has been made in these areas, but much work remains in expanding knowledge to develop such models. The issue is complicated in that in many cases, particularly in models of perennial crops and livestock, challenging problems in systems science arise in adequately modeling dynamic aspects. In any event, the simulation team must include people who can bring biological science (particularly crop science, animal science, and ecology) into the modeling process.

Still another important discipline in model-building is social science, mainly, although not exclusively, in the realm of sociology. Demography, the study of human populations and how they change with respect to size and age composition, is obviously of key importance to agricultural sector modeling. An important related topic is rural-urban migration. Some of the work in social science is providing better understanding of this phenomenon and a basis for modeling. Still another contribution of social science is in understanding and modeling attitude change, particularly as it relates to adoption of new technology in agricultural development. Other important disciplinary inputs to the modeling process from the social sciences include contributions from political science and public administration, industrial psychology, and law.

Physical science is another discipline important in constructing various kinds of agricultural models. In particular, now that energy has become a significant constraint in development, it is clear that much more needs to be done to assess the energy requirements of alternative policies. This can take place only if the simulation modeling team avails itself of appropriate disciplinary knowledge from physical science.

A variety of important disciplinary inputs must be brought into the model development process. These inputs can be provided by the simulation team members themselves, by the use of special consultants, or, in most cases, by both these means together. We turn our attention now to the final step involved in structuring a mathematical model before the mathematical model is ready to be implemented on a computer.

Final Step in Mathematical Model Development

Given that component models have been well defined and developed in terms of specific mathematical equations, it is usually a relatively simple matter to link the components together by appropriate mathematical equations. In many cases linking components together requires simple equations that equate component output variables to the appropriate component inputs to which they apply.

A final logical step before computer implementation is a coarse check on the validity or logical consistency of the model. Some key questions to ask at this point are the following:

(1) Does the model contain the major variables thought to be relevant in the given application (appropriate policy inputs, criteria for evaluation of performance, etc.)

(2) Is each model variable uniquely defined (defined once and only once)

(3) Is each equation consistent with accepted theory and constraints that may apply

(4) Is each equation mathematically correct

(5) Have components been properly linked

While these checks on model validity are never sufficient, they are a necessary beginning. Further discussion of the important matter of model validation and verification is found below, where the question logically comes up again--after computer implementation of the mathematical model.

Computer Implementation of the Mathematical Model

For all but the simplest mathematical models, it is necessary to use a computer to solve the model. By "solving" the model, we mean determining the logical consequences, as indicated by the response of the performance variables, that follow from the model structure, its data, and the policy and other inputs that have been specified. The objective of computer implementation is to develop a computer model that will indicate how the system performance variables (those variables used by decision-makers to evaluate alternative policies) are affected by changes in the policy inputs or changes in the model structure. It should be reemphasized that there is almost always error in the computer model. That is, the solution of the computer model is rarely, if ever, exactly equal to the true solution of the mathematical model. An important task of computer implementation is, therefore, to ensure that this approximation error is small enough to be neglected.

Prior to or in the early stages of computer implementation, data must be acquired which permit assigning values to the parameters or coefficients of the model and initial values for certain (state) variables. Included here might be elasticities which specify changes in demand or supply that take place due to changes in prices and income, coefficients that define the input requirements of various production processes, land areas, sizes of human and livestock populations, perhaps on a regional basis, parameters that determine population birth and death rates, and so forth. Econometric and other estimation methods from statistics and systems science are important here. It should be emphasized that data and estimates obtained therefrom are usually tentative at this point. Experience in testing the computer model often leads to insights into high-priority data needs which can guide further data collection and improvement in the data base of the model.

Choice of Programming Languages

A fundamental decision to be made early in computer implementation is the choice of a programming language for the model. First, a broad decision must be made whether to use a general-purpose computer language such as FORTRAN or a special-purpose language such as DYNAMO, GASP, or GPSS. A general-purpose language such as FORTRAN offers the advantages of adaptability to many model archetypes and computers and relatively economical model operation in terms of computer costs. Disadvantages include more difficulty (and higher costs) in programming. This is due in part to the extra programming work involved in making computer results easily interpreted by the user. Special-purpose languages, on the other hand, are much easier to program and usually have special output routines to aid in user interpretation of results. Disadvantages of these languages are often higher model operating costs and limited adaptability to model archetypes and computer types.

In specialized applications the special-purpose languages are a logical choice; however, experience has shown that in large agricultural sector models, a general-purpose language is often the only viable choice. The wide range of model archetypes employed is often the determining factor, though transferability of the model and its components among countries and computers can be a deciding factor. FORTRAN was the programming language chosen for both the Nigerian and Korean simulation models. The programming task in both cases was eased significantly by the use of special-purpose, FORTRAN-compatible software packages to handle, for example, linear programming, user-oriented tables and graphs, and basic simulation operations [1, 11]. Clearly, a simulation team is well advised to equip itself with the expertise and software necessary to use general- or special-purpose programming languages as particular applications warrant.

Before moving on to other aspects involved in implementing a decision-oriented model on a computer, it would be well to briefly discuss several special-purpose simulation languages that can be particularly useful for agricultural models. These special-purpose simulation languages fall into two broad categories. One of these has a macroscopic orientation; the other, a microscopic orientation. DYNAMO [15], in the former category, has been used extensively to simulate dynamic macroscopic economic, agricultural, and industrial systems. It is efficient and relatively easy to program. DYNAMO is useful for a variety of macro-level agricultural models that do not employ special features, such as optimizing methods. Two important simulation languages for simulating systems at a micro level are GASP and GPSS [14]. These languages would greatly facilitate the simulation of, for example, systems involving the transportation and storage of individual shipments of agricultural commodities. They have also been used in detailed simulations of farm operations. GASP enjoys the advantage of being FORTRAN compatible. It is therefore compatible with any agricultural model programmed in FORTRAN. A necessary condition for using any of these special-purpose languages is, of course, that it be available for the particular computer being used--a condition that is not always satisfied.

Choice of Computational Techniques

In system simulation there are significant decisions to be made in the choice of computational techniques used in the computer model. Proper choice here can lead to substantial savings in model development time and cost.

In almost every simulation model there is a need to represent the relationship between two variables or quantities in language a digital computer can understand. These relationships or "functions" can be represented in several ways. A very common and efficient means of doing this is the so-called "straight-line approximation" method, illustrated in Figure 1.

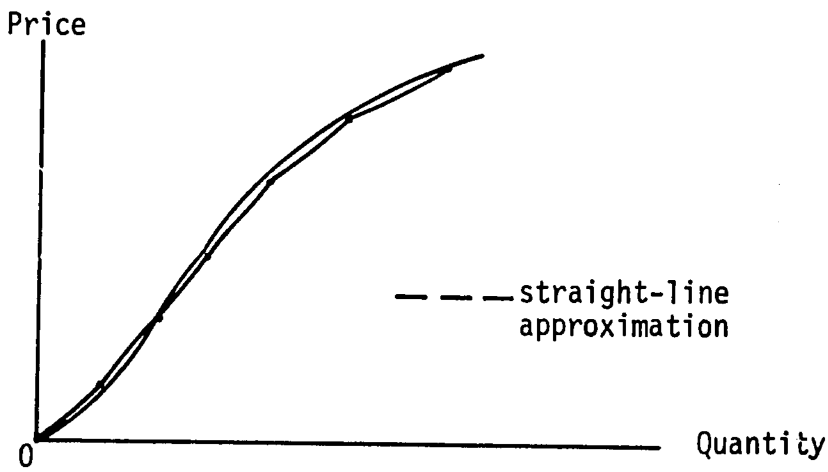

Figure 1. The Straight-Line Approximation Method of Function Representation

This figure illustrates the supply function for a product relating quantity supplied to market price. The dashed lines in the figure show a straight-line approximation to this supply function. There are a number of excellent special-purpose computer routines for efficiently carrying out straight-line function approximations in simulation models [11]. In some cases the functional relationship between two variables can be implemented with functions built into a programming language such as FORTRAN (examples are logarithmic, exponential, and trigonometric functions). Programming using "built-in" functions is easier, but they almost always use more computer time than the straight-line approximation method described above. Another method of function representation, polynomial approximation, can be extended to functions of more than one variable but is less common than the two methods cited.

When the system model contains differential equations, an important choice to be made is the type of integration procedure used in solving the differential equations. Differential equations are solved on a digital computer by the process of numerical integration; and there are several ways to do this, each with its own advantages and disadvantages. The simplest and most common numerical integration technique in agricultural models is the so-called "Euler" (pronounced "oiler") integration. It is very easy to program in complex models and is reasonably efficient in operation. Euler integration is the simplest member of the "predictor" family of integration methods. Higher-order predictor methods can be used in certain situations and can result in models which operate more efficiently but are more difficult and expensive to program. If high computational precision is sought (which it seldom is in agricultural models), the "predictor-corrector" or Runge Kutta methods of solving differential equations would be appropriate. Recall that the important "distributed delay" model archetype is structured using differential equations. A number of efficient computational packages have been developed for readily implementing distributed delays on digital computers [1, 11]. These can save a great deal of programming time, and a simulation team should have access to them.

Other computational packages can also aid significantly in implementing mathematical models on digital computers. Along with computational packages for implementing distributed delays, there is a corresponding set for implementing the discrete delays [11]. Further, there are packages available which interconnect delay models to provide more complex packages useful in implementing population models [1]. These have been used extensively to simulate populations of humans, trees, animals, etc., on a digital computer and are often important components in larger agricultural models.

Another important group of computational packages makes it possible to readily incorporate optimization into models. A number of packages are available for doing linear programming; however, great care should go into the choice of a particular package for a particular application, since there can be large differences in computer operating costs with different linear programming packages. Other optimization packages, such as COMPLEX and Powell's Method [4, 10] are available which, in some cases, can efficiently operate a simulation to find a set of decisions that will optimize a criterion of interest to decision-makers. These various optimization packages are sometimes used to simulate the optimizing or quasi-optimizing behavior of components (i.e., farmer behavior, merchant behavior) in agricultural models.

It should be clear that many computational packages are available which can aid significantly in computer implementation of mathematical models. It is economical to store a wide variety of these on magnetic tape or other permanent storage, which can make them readily available to a simulation team.

Preliminary Tests of the Computer Model

There are certain tests which should be carried out with the computer model to ensure that it provides an acceptable solution to the system mathematical model. Since the computer model approximation of the mathematical model is normally used to address the more fundamental issue of how well the mathematical model represents the real world, the adequacy of the computer model as an approximation to the mathematical model must first be established. Due to the wide variety of model types, it is not possible to provide an exhaustive discussion of possible computer model tests. Discussion will be limited to the most common tests that apply in a number of cases of interest.

One useful set of tests involves operating the computer model under conditions for which the solution of the mathematical model is known. If the computer model produces an acceptable approximation of the known solution under these conditions, we have evidence of its acceptability. It is sometimes possible to check the computer model against a number of these known solutions to provide considerable evidence regarding its acceptability. As an example, we may know that under certain extreme supply-demand conditions (in the mathematical model) supply should increase to limits determined by production and other constraints and that market price should stabilize at some high level. The computer model could be tested under the same conditions to determine whether or not it exhibits the required behavior.

A second set of tests determines whether or not the computer model satisfies a number of constraints that are built into the mathematical model. Included here are the conservation of flow and energy properties mentioned earlier and cost accounting identities (a special case of conservation of flow). Thus, a population model could be checked to ensure that the births, deaths, and migrations were in accord with changes in the sizes of population groups. In other cases we may know that certain variables in the mathematical model must behave in a prescribed manner. For example, prices must always be greater than zero. It is an easy matter to check such conditions in the computer model.

In models involving differential equations, there is another important test to be carried out in the computer model. In most of the important techniques for solving differential equations on a digital computer, the error in the computer model decreases as the step size[4] decreases. The step size is the time interval between solution points as the computer model steps through simulated time. For example, the step size in a computer model may be 1/12 year or one month. This means that the computer model computes model variables 12 times per year of simulated time. Mathematical theory tells us that in most cases the error in the computer model becomes very small as this step size becomes small. In these cases, then, the solution of the computer model should approach some fixed, limiting solution as the step size becomes small. The determination of an appropriate value for the step size in a computer model is an important decision. Improperly setting step size too large frequently causes the model to display spurious, unstable (explosive) behavior that only vanishes when step size is reduced to an acceptable value. The step size must be small enough to make numerical errors in the computer model negligible; but it should not be smaller than necessary, because computer operating costs increase rapidly as step size decreases. The cost of operating a computer model is directly proportional to the number of solution points, which is inversely proportional to the step size for a simulation over a given time horizon.

Model Credibility

Given that the computer model is an acceptable representation of the mathematical model, attention turns to the fundamental question of the adequacy of the mathematical model as a representation of those aspects real-world decision-makers are seeking to influence. In this section we will discuss some of the approaches that can be taken to establish evidence for the credibility of the mathematical model.

First, however, it should be noted that we are not dealing with a purely sequential process: model-building--computer implementation--validation--verification...this is, rather, an iterative process. Therefore, for example, during model validation and verification, we often find flaws or weaknesses that require modification or extension (more model-building). In fact, we often experience several rounds of this kind of iteration before we have a model we consider ready to use as part of the decision-making process. Also, we can never establish the credibility of a model of a complex, real-world situation with absolute certainty. The best we can hope to do is to not reject the model after applying the tests of coherence (validation), correspondence (verification), clarity, and workability as rigorously as possible. Significantly, even if we had a model that exactly represented the segment of the real world of interest, this would not preclude the possibility of error in the use of the model in decision-making. When the real world of interest in decision-making contains randomness or uncertainty (i.e., is stochastic in nature), the best a good model can do for us is to increase the likelihood of making right decisions.

The model checks for credibility are discussed below in the order they are normally carried out in practice. This order is determined by the ease with which the various checks can be carried out. There is no point in carrying out costly tests of a model that may be rejected and modified on the basis of less expensive checks or tests.

The first tests for validity normally conducted on a model are the so-called "logical consistency" checks. These have been discussed above as tests of coherence and are usually carried out as part of model-building and testing of the computer model. Given a model that has passed tests for logical consistency and tests that ensure that the computer model adequately represents the mathematical model, the model can be subjected to extensive sensitivity testing, the first phase of verification. Sensitivity testing involves making significant changes in values of model coefficients or parameters, normally one at a time, and observing the changes that result in the key outputs of the model. Often the parameters selected for sensitivity analysis are ones for which we have the poorest estimates. The model at this point should have the best possible parameter estimates, given the data at hand. These sensitivity tests provide two important kinds of information. They indicate where we need to collect better data to improve parameter values of sensitive parameters that have significant impacts on model outputs of interest. This information leads to priorities and efficiencies in data collection. Further, these sensitivity tests produce changes in model behavior that we can check against our knowledge of how the model ought to behave under the given circumstances. This leads either to further confidence in the model or to refinements to correct deficiencies encountered.

Sensitivity analysis can also be carried out by making significant changes in the policy inputs of the model. This provides further opportunities for checking model behavior; and, if carried out when the verification process is well along, it can provide useful insight into the most important policy inputs to consider during model implementation as part of the decision-making process.

As a result of extensive logical consistency and sensitivity tests, a model will be refined, more data will often have been acquired, and the model parameter estimates will have been improved. A model which has gone more-or-less successfully through these phases is a candidate for historical tracking tests. Such tests are also verification tests or, as discussed in Chapter 1, tests of correspondence. If historical data are available that describe how the real-world system has behaved in the past, a dynamic model can be operated to determine how well it is able to reproduce this past behavior that has been observed. These tests are often rather expensive to conduct and should only be attempted after the preceeding validation phases have been completed. Historical tracking tests will often result in further model refinements and data improvement and in additional evidence of model validation and verification, if the model is capable of reasonably approximating the past real-world behavior.

In some cases it is possible also to use historical tracking as a means of further refining estimates of selected model parameters. In this case suitable optimization techniques [10] are used to find values for these selected parameters that result in a "best" fit between model behavior and the past real-world behavior.

The ultimate test of the credibility of a model is how well it performs in practice in leading to more enlightened decisions which better serve the ends being sought. If a model has come through the above tests credibly in the eyes of the model-builders and, in addition, has passed the test of clarity with the ultimate users of the model,[5] it can guardedly enter the decision-making process for its final test of workability. A well-developed model will normally be able to make a contribution to the decision-making process. Use in decision-making will logically proceed gradually, with the model gaining a more significant role as experience warrants. Thus, model application in decision-making can be viewed, in part, as an extension of the validation and verification process.

A final comment on an important issue is necessary here before moving on to discussion of model implementation in decision-making. This is the need for clear and detailed documentation of the model. Models should be documented when they have been developed to the point where they can make useful contributions to decision-making. This means that, over time, documentation may be needed for several versions of a model as it evolves to meet the changing needs of the decision-making process. In many applications of models, inadequate time and money have been allocated to model documentation, and the result has sometimes been waste of scarce resources when new model-builders and programmers have had to pick up where others have left off. Good documentation of a mathematical model and its computer program should make it possible for new people to begin working with the model with relatively little consultation with the original model architects.

Model Implementation

While previous steps in the model-building process require significant interaction with decision-makers, particularly model validation and verification just discussed, effective model implementation requires a high degree of intensive and ongoing interaction among decision-makers, model-builders, and the results of creatively designed model tests. This interaction process and how it can creatively lead to improved decisions is discussed below. The interaction process can take place informally or through structured computer software; for example, a decision-oriented computer language, such as "PAL." Informal model application takes place as an on-going dialogue with computer results over an extended period of time. This dialogue often begins by knowledgeable persons (model-builders and/or decision-makers) designing a small set of preliminary, alternative policies for attaining the goals being sought. These alternative policies become inputs to the computer model, and the results for the various policies are computed in terms of a set of performance measures (i.e., incomes per capita, foreign exchange position, costs to government, etc.) for each alternative policy. Normally different policies produce different mixes of benefits and costs, and these are subjected to critical evaluation by decision-makers and others sensitive to the spectrum of needs policies must address. Often evaluation of policies must include factors that are not included specifically in the formal model, and it is very important that policy-evaluators have available information from other sources necessary to make such judgments.

Experience has shown that these evaluations of alternatives made explicit by computer models can lead to an improved set of policy options to be explored using the computer model. Model-builders often play a creative role in the dialogue leading to improved policies and are also needed at times to adapt the model to respond to the new set of policy options to be explored. In complicated decision issues a number of rounds of this kind of interaction may be required to arrive at an acceptable set of policy actions. These rounds of interaction using computer models can take place whenever it is appropriate to do so--as part of the budgeting process, prior to key decisions, such as determination of price policies or in the preparation of, say, a five-year development plan. Finally, this kind of ongoing model application can lead to a continual stream of model improvements as new information is acquired and as the needs of the decision-making process inevitably change over time.

In this interaction process it is important that the model display the consequences of alternative policies in forms that can be readily understood and interpreted. During model construction considerable effort often must go into the design of special tables and graphs that will readily communicate with decision-makers and evaluators. While this interaction process has been described as involving mainly decision-maker-evaluators and model-builders, computer programmers also play a vital role in preparing the model policy inputs specified and in operating the computer model.

Before leaving discussion of the use of models as part of the decision-making process, the subject of policy optimization should be briefly discussed to indicate the capability that is currently available with existing computer technology. In certain kinds of decision situations, it might be of interest to seek policies over time that will optimize some specific criterion of interest to decision-makers. Linear programming models have been used extensively to solve specialized kinds of (usually static) optimization problems; however, recent developments in technology [4] have made it feasible to solve certain kinds of dynamic optimization problems using simulation models. Using this approach, it might be possible, for example, to find a set of government commodity purchase and release policies that would attain some prescribed commodity price targets over time at near minimum cost to government. Solving these kinds of optimization problems usually involves substantial computer time and cost (in the thousands of dollars with sizeable models) but may be worthwhile in certain decision-making applications. Computer software is available for carrying out these kinds of optimizations [4]; and a system simulation team should have this software, as well as the knowledge and skills needed to apply it.

We have only briefly summarized an interactive process that can lead to creative contributions of models in agricultural planning and management. There are a number of important country-specific organizational and institutional questions which must be addressed in order to make viable model application feasible in specific decision-making situations. Suffice it to say here, the kind of close interaction described above is essential to fruitful model applications. If this potential is to be realized, organizational and institutional arrangements must be found which make this kind of interaction possible.

Conclusions

We have discussed in some detail the process leading to models which can play a useful role in agricultural sector decision-making. Experience has shown that if this process is carefully carried out by skilled and experienced people, it can contribute to effectiveness in attaining objectives of the decision-making process over time. However, the converse is also true--ill-conceived models can waste scarce resources and contribute little to the decision-making process. The key here seems to be a "skilled and experienced" model development team institutionalized as part of the decision structure. These important matters are discussed in the following two chapters.

FOOTNOTES

[1] Differential equations contain derivatives or rates of change of system variables. Difference equations contain past, as well as present, values of system variables.

[2] In this case, the range 1,900-3,000 is called a "95-per-cent confidence interval for the outcome." Confidence intervals for other percentages can easily be computed from Monte Carlo analysis.

[3] An "operating condition" is loosely defined as sets of input and output flows that are mutually consistent, given the input-output characteristics of the producing units in the economy.

[4] This step size is often called Δt, DT, or "h" in the literature of simulation models.

[5] Clearly, model-users (decision-makers) must have had sufficient experience with the model and the real world to make meaningful evaluation possible.

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CHAPTER 4

INSTITUTIONALIZATION OF INVESTIGATIVE CAPACITY

Francis C. Jones
George E. Rossmiller

Introduction

Development of a problem-solving investigative capacity includes institutionalizing that capacity as an integral part of the decision structure. Little, if any, contribution is made toward developing an indigenous investigative capacity when the World Bank sends a short-term team into a country to conduct one of its periodic economy surveys, when a consulting team is called in to do a feasibility study, or when a specialist is brought in to consult on a specific technical problem. In each of these cases the parameters of the problem or problems are prescribed *à priori* and the objective is to move in quickly, gather the secondary data and information necessary to the required analysis, draft the report, and leave. While these activities are important in their own right, they are not of concern here.

Of concern is the institutionalization of an investigative capacity within some form of administrative unit, composed of a core of professionals capable of amassing, analyzing, and synthesizing data and information within a problematic, logical framework in such a way as to provide decision-makers with an understanding of the likely consequences of possible alternative courses of action. The information and data, and much of the analysis and synthesis, must include knowledge from a variety of areas. These include the technical level and relationships within agriculture, the economic situation and structure, the social and cultural conditions, the state of human change, the institutional environment, and the political processes and their constraints. Thus, the investigative unit must have the capacity of drawing upon knowledge and abilities from a variety of sources in government, the university community, and the private sector.

Institutionalization

Institutionalization, as conceptualized here, is the process through which the investigative capacity, in this case including simulation models and their attendant trained manpower, is focused through an investigative unit positioned in the agricultural decision-making structure in such a way and at such a location that optimum interaction with, and utilization by, decision-makers will take place, thus guaranteeing functional continuity of this capacity. In other words, this section does not deal with model-building per se (see Chapter 3) nor in a detailed way with training to build the professional indigenous capacity to operate the models (see Chapter 5). Rather, it deals with the organization, interactions, and linkages necessary for continuing optimum usage of an investigative capacity by decision-makers in the form of an investigative unit institutionalized in the decision-making structure. It also deals with establishing the capacity of indigenous researchers, analysts, and policy-makers to use the models in designing, analyzing, and evaluating policies, programs, and projects. As indicated in Figure 1, the investigative linkages are to decision-makers, on the one side, and to support and service agencies, including data and information acquisition systems, computer services, technical agricultural research units, universities, and other research institutions, on the other side.

The overall process of institutionalizing an investigative capacity in which organizational, technical, and human change are required is an extremely complicated venture at best. The process must begin within the context of a given political ideology, human resource base, technological level, and configuration of institutions and their linkages with each other.

Certain prerequisites must be present before any attempt is initiated to build this capacity. There must be a recognition by key decision-makers that policy and planning objectives are not being fully realized and that this is due in part to the lack of information and reliable analysis upon which decisions are based. There must be a demonstrated intent and will to improve the agricultural decision-making process with a more scientific and analytical approach. There must be the will and the ability among the appropriate decision-makers to commit the manpower and financial resources necessary to such an endeavor. Finally, appropriate decision-makers must be willing and able to make necessary organizational changes in their planning and policy determination system in order that the new investigative capacity may be properly institutionalized and effectively utilized in improving policies, programs, and projects.

While the unique configuration of institutions and complex of responsibilities will dictate to some extent the latitude and scope of responsibilities, linkages, and functions delegated to an investigative unit, some basic principles generally apply. Figure 1 indicates a conceptualization of the functional linkages necessary to integrate an investigative unit into the decision structure.

The investigative unit is shown in the middle, with the units providing support and services indicated in the lower part of the chart and the functional units or agencies being served by the analytical unit shown in the upper part of the chart. The I (for interaction) in the circles on the arrows depicting the linkages indicates the importance of interaction between the analytical unit and *all* other units with which it is linked. The heaviness of the arrows indicates the likely relative operational importance of the linkage. Finally, the analytical unit is shown to have two subunits--one concerned with further development, adaptation, and testing of the models, techniques, and methodologies used by the unit, and the other concerned with operational use of the investigative tools in analysis of problems defined in interaction with the decision-makers.

Linkages to Decision-Makers

The relationship of the investigative unit to decision-makers at a variety of levels in the national government is obvious in Figure 1. A major product of this interaction is a two-way information flow as problem definition, data collection, and analysis take place. At the general-economy-planning and the agricultural-planning levels, the analyses will focus on long-term consequences of broad planning and policy strategies. At the agricultural, production, and food-management

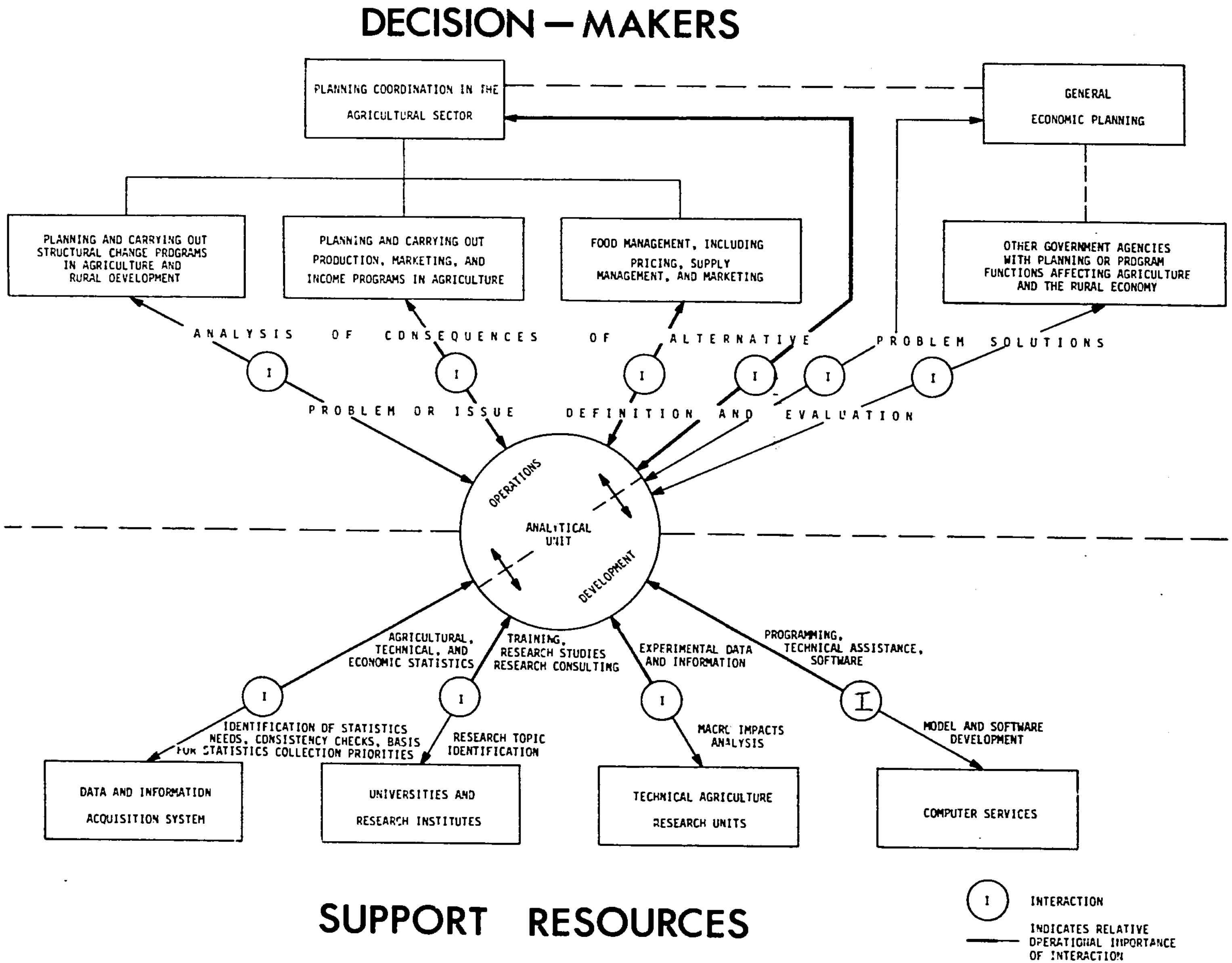


FIGURE 1. THE ANALYTICAL UNIT IN THE DECISION STRUCTURE

levels, the analyses will focus on intermediate and short-run consequences of policy implementation and program alternatives. Problems at each level must be defined in interaction with relevant decision-makers and within the realm of authority of the particular decision-maker.

A caveat is necessary with respect to Figure 1. The only part of the decision-making system shown is that which impinges directly on the investigative unit. Input to the decision process by the investigative unit is only one of many inputs from a variety of sources. The inputs available from all sources are weighed and sorted, accepted or rejected by the appropriate decision-maker for any given decision.

The strength of the input by the investigative unit depends upon the nature of the problem concerned, the relative value placed upon the input from the investigative unit by the decision-maker, and the relative importance of information and implications not within the purview of the investigative unit, for the decision-maker is always attempting to satisfy multiple objectives within an arena of multiple constraints--political, institutional, technical, and human, as well as socio-economic.

Linkages to Support Resources

The resources required for effective institutionalization and utilization of an investigative capacity within an existing decision-making structure can be categorized into (1) a data and information acquisition system, (2) other research units, (3) a computer support system, (4) trained personnel, and (5) organization and administration for planning and policy determination.

Data and Information Acquisition System

An extremely important supporting service linkage is with the data and information acquisition system. This system provides the important function of quantitatively measuring the structure, performance, and behavior of the agricultural sector and relevant parts of the general economy. The statistics collected should be processed and disseminated in a form most helpful to the users, in this case the investigative unit and the planning and policy decision-makers. Close interaction between the investigative unit and the acquisition system can provide the basis for data improvement. The investigative unit, through the use of its models, can provide information on consistency and data sensitivity which can be helpful to the acquisition system in determining what statistics to collect and how they should be processed and in establishing guidelines for priorities in data refinement for greater accuracy. The quality of the data and information generated by the acquisition system is vital to the quality of the output going to decision-makers from the investigative unit. To be of most use in the decision process, the flow of data and information from the acquisition system must be relevant, accurate, timely, and consistent. It is against these criteria that an agricultural statistics collection and data system should be evaluated.

Relevance. Sound planning cannot be done without data which measure those variables with which the decision-maker is concerned. Further, the raw data or measurements often must be processed in some way--aggregated, disaggregated, converted to another form, transformed, inflated, or deflated--to become a reflection or true measure of reality.

thus, relevant data are those which are in a form which best helps in understanding the problem under study.

Accuracy. Measurements can be only as precise and unbiased as the instruments and the collection method used and the ability and care exercised by the people and institutions involved allow. Accuracy is also a relative concept, and the degree of accuracy required of any data must be determined in the context of their use and the sensitivity of the result to them. Data and statistics are costly to obtain, and the cost normally increases with the degree of precision. The degree of accuracy to be obtained is an economic problem of determining where the marginal cost of increased precision is equal to the marginal revenue of that precision level (or the marginal cost of not obtaining that precision).

Timeliness. Planning and policy decision and program and project design adjustments must be made in a specific time context to be effective. Data and analysis upon which these decision are based must be available when needed in order to be of maximum usefulness. Diligent administration and management of the data and information system, with particular emphasis on meeting deadlines, is necessary to insure timeliness.

Consistency. Consistency has meaning both over time and among the data collected at any point in time. Consistency over time requires that the same measurements be taken at equally spaced intervals of time to develop data time series. Consistency among data collected requires that it be precisely defined and that the concepts provide a link from one form of data to another, so that it all "checks out."

Other Research Units

The supporting linkages with universities, technical agricultural research units, and other research and analysis institutions are also vital. Through these linkages a continuous flow of information, research and analytical results, and trained personnel from relevant disciplines can be accomplished. Since much of the trained intellectual capacity of a country normally resides in these types of institutions, much can be gained through establishment of close working relationships with those willing to do so. One means of facilitating a working linkage is governmental provision of resources required to carry out research and analytical efforts of mutual interest and of use to the governmental planning and policy determination function.

Computer Support

Computer service support is also critical. Computer installations will vary substantially from one country to another with respect to hardware capacity and configuration, software availability, administration, and cost.

Development and institutionalization of the general system simulation approach to sector planning and policy decision-making requires access to adequate computer facilities by the investigative group responsible for development and utilization of the models--adequate in terms of the size and capacity of the computer, availability of the right kind of software, and the "operational mode" of the computer installation.

The size of most agricultural sector models requires large-scale computers. The large model size results from the variety of different policies which decision-makers would like to explore; the levels of disaggregation in terms of number of commodities, regions, etc.; and the number of model components and the types of analytical techniques employed--particularly those involving matrix manipulation. Computers in the class of the CDC Cyber Series, the IBM 370 Series, and the Univac 1100 Series, or their equivalents, would usually have sufficient capacity to run these models.

Any large-scale computer would have the FORTRAN language (software) available for programming the models. The rationale for the use of FORTRAN was discussed in Chapter 3.

The "operational mode" of the computer installation can greatly affect the time it takes to develop a system simulation model. Computer installations vary greatly in terms of their management and operational style. There are a number of dimensions which affect operational style, but computer installations can be grouped into those which are oriented toward production work (e.g., preparation of payrolls, budgets, and general data processing) versus those which are oriented to research, analysis, and development of new software systems. Usually, a research-oriented computer is managed by a more highly trained and technically sophisticated staff. Also, the research computer will likely provide time-shared, interactive, on-line access to computers, while the production computer will likely utilize the batch mode of operation. After a model is developed and stabilized in its development through use of a research-oriented computer, it can then be easily run in production mode on a production-oriented computer.

The investigative group responsible for developing and operationalizing policy-planning models should be given access to adequate, research-oriented computer facilities. If necessary, the investigative unit should be provided with a budget to purchase computer time from commercial facilities if the government facilities, which are often provided cost free, are not adequate to do the job because of their production orientation.

Trained Personnel

Development and institutionalization of a computer model-based investigative capacity requires highly trained people for model development, capable administrators with a high level of organizational skills, and well-trained agricultural economists with an understanding of the system simulation approach to sector analysis located at various strategic points within the governmental agencies dealing with the agricultural sector. The latter perform the very essential function of establishing, within the action/decision-making agencies, a climate favorable to the utilization of the models in solving agricultural development problems.

Model development requires highly trained people in the fields of systems science, computer science, agricultural economics, econometrics, technical agriculture, and statistics. The following chapter discusses system simulation team composition and training requirements in detail.

Organization and Administration

Since the institutionalization and utilization of the investigative capacity is a complex operation and in many countries will require a considerable reorganization of the planning and decision-making apparatus, people with high levels of administrative and organizational skills are required. The administrative and decision-making organizational structure should provide an environment in which access, coordination, and information flows among decision-making units and between them and the analytical units are facilitated. Unless the involved government agencies are organized for effective vertical and horizontal coordination at all levels, administrators and decision-makers have little incentive and, in some cases, little opportunity to develop a capacity to absorb and utilize centralized investigative input into the planning and policy process.

Constraints to Institutionalization in Developing Countries

Available resources for institutionalization and utilization of the investigative capacity in most developing countries fall considerably short of the resources delineated above in terms of both quantity and quality.

With respect to the data and information acquisition system, data systems in most countries grew and became institutionalized piecemeal, as needs were identified and as resources were made available. As a result, statistics are often inadequate, inaccurate, inconsistent, and thus fall short of the quality needed for sound research, analysis, and planning. The publication process is often very slow, and the greater the delay in publication or dissemination the greater the loss in usefulness--in many cases a total loss. Often, too, there is inadequate interaction between the collectors and users, relative to the users' needs and what the collectors can provide.

With respect to hardware and software systems, many developing countries have procured or are procuring the systems required. Consideration cannot be given to building the type of investigative capacity described here unless adequate hardware systems are present and appropriate software is available.

With respect to trained personnel, the system simulation approach to planning and policy decision-making for agricultural sector development involves a conceptual framework and quantitative methods which are not part of the background of most professionals in developing countries. Further, in many, if not most, countries these areas are either not taught or are not taught appropriately. Thus, development of an indigenous capacity to apply the systems approach and its various quantitative methods requires a substantial investment in education. Initially, the bulk of this training will have to be in the developed countries.

With respect to organization for planning and policy determination, in many, if not most, of the developing countries, planning flows verically from minister to bureau to division and vice versa. Often there is no meaningful exchange of ideas or views horizontally between bureaus or divisions. Planning functions tend to be scattered throughout the bureaus and divisions, resulting in inconsistencies and a large degree of autonomy for individual bureau activities which are not well coordinated, even though so-called "coordinating offices" may exist at the top of the organizational structure. Further, while capable administrators usually exist, very seldom have they been trained in the organizational skills required to put together a modern planning system utilizing sophisticated analytical tools. This requires new concepts of organization and management.

Deficiencies in data and information acquisition systems, trained personnel for model-building and institutionalization, and organization for planning and policy determination can be corrected through bringing in outside professionals to work with indigenous personnel on these problems, while at the same time sending indigenous personnel overseas for the required training. The provision of these professionals and assistance in overseas training is a proper function of foreign assistance agencies.

There are probably only a few developing countries presently having the prerequisites necessary for the development and institutionalization of agricultural sector simulation models as a part of an investigative capacity. Only countries with the attributes spelled out in this chapter can hope to achieve the integration of such a sophisticated investigative capacity. Through well-planned efforts and given enough time, an indigenous investigative capacity can be institutionalized within the decision structure of a developing country and effectively utilized for planning and policy decisions.

CHAPTER 5

EDUCATION TO BUILD HUMAN CAPACITY

Thomas J. Manetsch

Introduction

By its very nature a systems approach to planning agricultural sector development involves a conceptual framework and quantitative methods which are not part of the background of most professionals in developing countries working in this area. Further, in many cases these areas are not taught, or not taught appropriately, in the developing countries. It follows, then, that development of indigenous capacity to apply this approach and its various quantitative methods requires a substantial investment in education--formal and informal. It also follows that at least part of this education must be acquired abroad. In this chapter we will analyze in some detail the types of people required to carry out the functions essential for effective model development and application. We will then discuss education programs for producing the requisite manpower. The chapter concludes with an examination of some problems and obstacles to the development and operation of a viable system simulation team and some means of addressing these problems. In the following we assume that a system simulation team is to be developed within a government decision research unit serving agricultural sector decision-makers at various levels.

Analysis of the Human Resource Needs of a Viable System Simulation Team

The development and application of models at the project, subsector and sector levels in developing countries involves a number of essential *functions* which must all be carried out effectively in order for the models to contribute usefully to agricultural sector development. These functions include:

1. Data acquisition, storage, and updating
2. Model development
3. Estimation of model parameters
4. Model testing and validation
5. Use of models in decision analysis
6. Model refinement and updating
7. Model documentation

Experience has shown that carrying out these functions effectively requires not only the integration of many disciplines but also unique kinds of people who perform well as members of multidisciplinary teams.

Data Acquisition, Storage, and Updating. The primary disciplinary inputs required here are statistics and computer programming, along with substantial knowledge of the economy and its data. A trained statistician is needed to supervise data acquisition and processing and to coordinate with government statistics units; however, other experienced people who know the economy and its data will play a vital role in selecting among data sources and in "massaging" data if the statistician does not have this background himself. This function depends heavily upon the rest of the simulation team for guidance in the determination of *what data* are required to support the overall analytical effort and in what forms they should be stored in order to be compatible with model applications.

<u>Model Development</u>. The model development function is probably the most demanding of disciplinary depth, as well as breadth. In most cases experienced systems analysts and agricultural economists at the Ph.D. level are needed to organize and carry out a viable system modeling enterprise. A common pattern is several key people working together having backgrounds which in part overlap and in part complement one another. These people must have a strong background in mathematics and statistics and have operational competence in system dynamics, control theory, system optimization (including linear programming), computer programming, and estimation techniques (including methods of econometrics). Further, they must have a demonstrated ability to creatively relate mathematical abstractions to real-world phenomena in a way that captures the essence of the problem being studied without excessive detail. This involves being steeped in the "systems approach" as a problem-solving methodology. In order to be effective model-builders, they must also have good basic grounding in economics, an ability to rapidly assimilate other disciplinary knowledge relating to the real world being modeled, and have a good feel for how the world being modeled "works." All this is, of course, a tall order; but it is a realistic assessment of what is needed to develop the broad range of models needed in agricultural sector analysis. While development of these people is not an easy matter, comfort can be taken in the fact that it has been done and that some of these people *do* exist.

The above discussion is not to imply that the systems analysts and agricultural economists can carry out model development functions alone. A number of other people also must play key roles in providing informational inputs needed for model development. These inputs include more economic theory, biological and other knowledge relating to technical agriculture, and a mass of information describing how the system being managed "works." Of particular importance, of course, is interaction with decision-makers to ensure that the model-building objectives square with the real-world problems being addressed. A key requirement in all model development is competent computer programming.

Estimation of Model Parameters. Parameter estimation is the process by which values are estimated for model parameters using data which have been acquired from the real world. The two main approaches available for estimation of model parameters are classical econometrics and a set of system identification techniques which has grown out of systems science. A viable simulation team needs the skills to utilize both of these approaches. While well-prepared systems analysts and agricultural economists will be able to do a considerable amount of parameter estimation using econometric methods, they may not have the expertise required to handle some of the more difficult issues that sometimes arise. Someone on the simulation team, perhaps an agricultural economist or statistician should have in-depth preparation in econometrics. A well-prepared systems analyst can be expected to have the background necessary to use system identification techniques from systems science in parameter estimation. Of key importance is a set of optimization techniques from nonlinear programming which makes it possible in certain cases to estimate unknown parameters in large simulation models.

Model Validation and Verification. This function is very much a team effort. It is also very much related to the model-building process in that validation and verification often indicate shortcomings which lead to further model refinements. Systems analysts and agricultural economists are therefore heavily involved in this function; however, others who have a feel for how the model "should work" play key roles. It is sometimes possible to get decision-makers involved at this point as consultants and critics. This can be very important in further developing decision-maker familiarity with the model and appreciation of its capabilities and limitations.

Use of Models in Decision Analysis. The central figures at this point of model application are the decision-makers. It is, however, necessary for them to interact effectively with economists, systems analysts, computer programmers, and perhaps others who know the model and how to use it creatively. In the early stages of model application in decision analysis, the model-builders themselves are often the only people capable of interacting with decision-makers. In the longer run, however, policy analysts will likely be required to provide a liaison function between the model-builders and the decision-makers. Interaction with decision-makers in addresssing policy questions often will indicate areas where models need modification or extension to provide a needed capability. Interaction among decision-makers, policy analysts, and model-builders is also needed here to precisely define the model changes that are required.

Model Refinement and Updating. This function in the overall process, like model development, is very demanding in terms of disciplinary breadth and depth. Ideally the team responsible for model development should implement this function as well, and it is very important to keep a productive team working together on a more-or-less permanent basis. If new people must be recruited, great care must go into selection. Experience has shown that the wrong people at this point can easily set a modeling effort back substantially.

Model Documentation. The purposes of good model documentation are twofold: (1) to provide a clear technical description of the model which can lead to refinements and extensions and (2) to provide information needed to use the model intelligently in problem-solving. The technical documentation is best written by the model-builders and computer programmers who originally constructed the model. The user-oriented documentation is best developed by those on the simulation team most familiar with model applications to decision-making. A computer programmer familiar with model operation in decision analysis should prepare a special section of this user's documentation for other programmers who may be responsible for model operation during applications.

Profile of a Team Capable of Implementing These Functions

The seven basic functions described above are all necessary for successful institutionalization of agricultural sector models. Other necessary conditions for institutionalization, outside the scope of this discussion, are detailed in the following chapter. As we have seen, each of the functions requires a somewhat different mix of professional talent. The carrying-out of each function requires people who are well prepared in at least one discipline and who, at the same time, have varying degrees of expertise in other relevant disciplines. These "overlapping backgrounds" among key team members are *essential* to the operation of a team that is attacking multidisciplinary problems. We can gain insight into the spectrum of personnel requirements for implementation of the approach by looking carefully at each of these seven functions and asking ourselves,

1. What *levels of expertise* in what *disciplines* are required to successfully implement the seven functions?

2. Assuming that each disciplinary specialist on the team must be able to contribute to each of the seven functions, what mix of disciplinary competencies must *each specialist* have in order for him to be a productive member of a team carrying out the seven functions?

Table 1 is an analysis of the disciplinary and personnel requirements of a system simulation team based on the above analysis and experiences to date in Nigeria and Korea. This analysis assumes that all personnel are specialists in one discipline with varying degrees of expertise in other relevant disciplines. The various *participants* (not necessarily one per discipline) are listed in the leftmost column of the table. Across the top of the table are listed the various disciplines necessary for carrying out the various functions. The rightmost column tabulates the level of involvement required of each disciplinary participant to effectively carry out responsibilities. Level of involvement may range from "consultant" up through 100 per cent.

The numbers in the table denote the approximate levels of competence required of each team participant by discipline. In some cases this preparation can be acquired through experience in service. Reading across the table, then, we get an educational *profile* for each team participant. Six levels of *disciplinary* competence have been identified:

Table 1. Participant/Discipline Profiles for an Effective System Simulation Team

Levels of Preparation Required:	Disciplines								Level of Involvement
	Various areas of technical agriculture, as appropriate; i.e., crop science, soil science, animal science, etc.	Computer Science	Agricultural Economics and related economic theory	Econometrics	Public Administration and Policy	Sociology (areas relevant to rural development)	Systems Science	Statistics	
Participants									
Agriculturalists	1-3	6	5	6	5-6	5-6	5	5-6	Consultant
Computer Scientist (senior programmer)	5	3	5	5	5	6	4	4	100%
Agricultural Economist	3-4	4-5	1	1-2	4	4-5	4	4	100%
Public Administrator	5	5	4	5-6	2-3	5	5	5	Consultant-25%
Sociologist	4-5	6	5	6	5	1-2	5	4-5	Consultant
Statistician	4-5	4	4	2	5	5	4	2	100%
Systems Scientist	4-5	4	4	4	4-5	5	1	4	100%

1. Ph.D.[1] plus experience
2. Master's[1] level plus experience
3. Bachelor's[1] level plus experience
4. Intensive professional course or strong minor plus experience
5. "Short course" or equivalent experience (perhaps acquired in service)
6. None

Some approximate numbers have been inserted in Table 1 to indicate the kinds of professionals experience has shown are necessary to effectively implement the seven basic functions at the sector level in Nigeria and Korea. For example, the table indicates that experienced agricultural economists at the doctoral level are needed and that they must have varying lesser strengths in systems science, agriculture, computer science, econometrics, public administration, sociology, and statistics. The same is true of all participants--the systems scientist(s) must have varying levels of preparation in economics, technical agriculture, and so forth.

The main conclusion we draw from this is that a variety of educational programs must be available which will provide various levels of preparation for specialists from many fields. Many of these needs can be satisfied by "appropriate" degree programs at the bachelor's, master's, and doctoral levels. "Appropriate" here includes the flexibility to put together degree programs which include necessary related disciplines as part of a degree program in a major field. In many cases degree programs at U.S. universities have this flexibility.

It is also clear that the spectrum of educational needs cannot be met by degree programs alone. There are many qualified and experienced professionals in developing countries (economists, administrators, agriculturalists, etc.) who could become productive members of a quantitative sector analysis team, given well-designed short courses or training programs in key areas. In the following section we discuss in more detail the structure of educational programs needed for equipping various members of a system simulation team. Following the pattern established in Table 1, we discuss educational programs for systems scientists, agricultural economists, administrators, computer programmers, statisticians, and the lesser-involved specialists noted in Table 1.

Education of System Simulation Team Members

Systems Scientists

As indicated in Table 1, systems scientists should be prepared through the doctoral level. Experience has shown that these people should have an undergraduate degree in a strong quantitative field, such as engineering, mathematics, or statistics. If the undergraduate background is in mathematics or statistics, it is very important that the individual be interested and skilled in the application of quantitative methods to *practical problem solving*. The course work preparation for systems science team members should include:

Systems Science

1. Systems approach as a problem-solving methodology
2. Linear system theory (graduate level)
3. System modeling
4. System simulation (heavy emphasis on continuous systems described by differential and/or difference equations)

5. Classical and modern feedback control theory (graduate level)

6. Optimization methods (including linear programming, nonlinear programming methods compatible with large simulation models, and at least an introduction to optimal control theory)

7. System identification techniques (including those compatible with large simulation models)

Economics and Econometrics

1. One year or more of micro- and macro-economic theory (at senior or first-year graduate level)

2. At least one course in econometrics emphasizing practical estimation techniques

3. Two or more "practical" economics courses emphasizing topics such as benefit/cost analysis, public program analysis, market behavior, economic development, trade, and agricultural policy

Computer Science

1. Courses that deal with advanced FORTRAN programming and a simulation language, such as DYNAMO or CSMP

In a number of universities, though by no means all, it is possible for a Ph.D. candidate in systems science to include the range of collateral material above as minors of his program. It is imperative that the systems scientist undertake an economic system analysis (involving modeling and simulation) as a doctoral dissertation.

Agricultural Economists

Agricultural economists also should be trained through the Ph.D. Such people should be "generalists" in their field and have substantial background in economic theory, production economics, marketing, development, trade, technical agriculture, and agricultural policy. The background in policy is of particular importance, as agricultural economists are likely to be primary linkages with the decision-makers, who are ultimately the "clients" of the systems team. To be most effective as part of a system simulation team, the agricultural economists should have a quantitative bent and background in mathematical programming (including linear programming) and econometrics.

In addition to this rather substantial background in the major area, agricultural economists should build the following material into the minors of their Ph.D. programs:

Systems Science

1. A working knowledge of the "systems approach" as a problem-solving methodology
2. An introduction to linear system theory and system simulation
3. An introduction to the techniques of system simulation (again with emphasis on systems described by differential and/or difference equations

Mathematics and Statistics

1. Mathematics through (at least) introductory calculus and matrix algebra
2. A year of probability and statistics, including regression analysis

Computer Science

1. A working knowledge of FORTRAN computer programming

Technical Agriculture

1. Crop science
2. Soil Science
3. Animal Science

Sociology

One or more selected courses in sociology related to rural development. Ideally, the dissertation in agricultural economics should involve policy analysis for agricultural development.

Administrators/Decision-Makers

While systems scientists and agricultural economists require a great deal of formal education, the training needed by administrator/decision-makers for effective interaction with a system simulation team is likely to be more informal in nature. A short course or seminar of perhaps two weeks duration dealing with applications of systems methods and models can be very useful, though it is certainly possible for these people to pick up needed orientation by informal interaction with the system simulation team. Important content for such a short course or seminar would include

1. A systematic presentation of the systems approach to decision-making *laced with practical examples*
2. A thorough discussion of the capabilities, limitations, and applications of the most important quantitative tools including
   a. Benefit-cost analysis
   b. Linear and nonlinear programming
   c. Regression analysis and econometrics
   d. Dynamic simulation models
3. "Hands on" experience in the application of models to practical decision-making using well-designed case studies and associated models

While this kind of formal training can be very useful, there is an ongoing need for informal training as decision-makers interact with the systems team in problem definition, model evaluation, and model use as part of the decision-making process.

Computer Programmers

Good preparation for computer programmers for system simulation teams is a bachelor's degree in computer science. Emphasis in this degree should be on programming (advanced FORTRAN and other selected languages, such as COBOL, DYNAMO or CSMP), data processing, and application of specialized software, such as statistical analysis and linear programming packages. The bachelor's program should also include basic economics, calculus, differential equations, matrix algebra, numerical analysis, basic probability theory and statistics, and an introduction to systems science.

Statisticians

Education through the M.S. is appropriate for a team statistician. Emphasis in the major field should include probability and statistics with a strong application orientation in agriculture and economics, survey design and implementation, and advanced work in econometrics. Education in minor fields should include technical agriculture, economics, computer programming and data processing, and an introduction to systems science.

Use of Special Nondegree Training Programs

The educational programs discussed above are for the most part formal baccalaureate or graduate programs. This appears to be a viable means of satisfying most of the educational needs of system simulation team members, *if the universities are carefully chosen*. In each case team members require substantial strength in essential areas which relate to the major field of study. Universities chosen should (1) be able to offer strong programs in the minor as well as major areas and (2) allow flexibility in the design of degree programs which include strength in the necessary minor areas.

While regular degree programs appear capable of satisfying most of the educational needs of a system simulation team, experience has shown that there are special needs which are best served by special, nondegree training programs. A case in point is the special short-term training for decision-makers and administrators cited above. Such training, perhaps in the form of short courses or workshop-seminars, can be offered directly in the developing countries. This has been done to a limited extent during the course of the Korean projects. A week-long seminar was held in summer, 1973, for government officials from the Ministry of Agriculture, staff from the College of Agriculture at Seoul National University, and a smattering of personnel from other governmental agencies. While the event was generally regarded as successful in introducing the system simulation approach and its capabilities, lessons were learned that can lead to improvement in the quality of such an experience:

1. More time is needed--two weeks is probably a minimum

2. More needs to be said about the practical applications of a wider range of quantitative methods (benefit/cost analysis, linear programming, perhaps PERT, etc.)

3. More "hands on" experience in the *use* of quantitative methods in decision-making is needed

4. A revised format is needed which eases the problem of busy people being called away by the demands of their jobs

There is also a need for longer-term nondegree training for economists, researchers, and certain other professionals who need a more in-depth understanding of the system simulation approach and related techniques. Such people usually will be working closely with, if not as a part of, a system simulation team. Special nondegree training programs are necessary where individuals either do not need a regular degree program or find it impossible to spend the time required to complete an appropriate degree program. As part of the Korean projects, a one-year, nondegree training program was designed to address these needs. This program was offered three successive years at Michigan State University--primarily for Korean agricultural economists associated with the MSU Korean project but including both U.S. students and students from other countries. The program included basic courses in systems science and computer science and allowed participants to elect a range of courses needed to enhance quantitative skills and broaden their background for work as part of a multidisciplinary team. The program also included a relatively intensive emphasis on projects which applied methods learned to practical problems.

In retrospect, this one-year training program appears to have been more or less successful in providing understanding of the system simulation approach and its capabilities and limitations as a means of addressing practical development problems. It was less successful, however, in producing a substantial level of expertise in the development of models for use in decision analysis. About half of the participants acquired significant model-building skills and half did not. In part the mixed success enjoyed was due to the candidate selection process. Other difficulties with this kind of program are the additional costs required to provide special instruction not available through regular university courses and "low status" for participants relative to regular degree programs. On balance, while regular degree programs are to be preferred as means of developing system simulation team members, special nondegree programs can be an important complement for carefully selected participants.

Criteria for Selecting Team Members and/or Trainees

Selecting members of a system simulation team is an extremely important task which must be done with care. In many cases this will mean selection of people to be trained for specific team positions. Important general criteria which apply to all team members are first discussed, followed by a discussion of specific criteria for selecting team systems scientists (since these people are normally the most difficult ones to acquire in developing countries).

Following is a set of general characteristics that experience has shown to be important for members of system simulation teams:

1. Good basic education
2. Above average intelligence
3. An interest in solving practical problems and, in particular, an interest in the problems of rural development--*problem* focus as opposed to discipline focus
4. A willingness to learn and work outside one's own discipline
5. Willingness to work with other people toward common goals
6. Effectiveness in interpersonal communication, including a propensity to *initiate* communication when necessary
7. Command of the English language, if education in the U.S. is indicated

Clearly selection of team members is not an easy task and, unfortunately, experience has shown that the effectiveness of multidisciplinary efforts can suffer severely if these basic requirements are not substantially met. A questionnaire was developed as part of the Korean projects to aid in identifying people with these general characteristics. It is designed to be used in conjunction with interviews, personal references, and specialized aptitude tests in an integrated selection process developed by Mehrens and Downing.[2]

Some specific, special criteria for selecting team systems scientists or, more likely, candidates to be trained at the Ph.D. level for this position include

1. Distinguished completion of quantitative bachelor's and master's degree programs, such as in engineering or mathematics
2. Demonstrated ability to use mathematics in problem-solving and good basic education in mathematics
3. An ability to creatively relate mathematical abstractions to the variety of real-world phenomena significant in agricultural decision analysis
4. An ability to capture the essence of a complex, real-world problem and reject extraneous considerations
5. Persistence in the solution of complex, long-term problems
6. An ability to break a complex problem into meaningful subproblems
7. Organizational ability to coordinate a complex whole, delegating responsibility appropriately
8. Related skills in personnel management

Management-oriented skills are important because model development often requires coordinated teamwork to accomplish a variety of interrelated tasks. The questionnaire referred to above also can aid in the selection of team systems scientists. In addition, personal interviews, references, and specialized aptitude tests can be helpful in selecting team systems scientists. Mehrens and Downing[2] discuss this selection process in depth.

Some Problems and Possible Solutions

Some problems have become apparent in the MSU Korean project's attempts to develop host-country system simulation capability. One basic problem encountered is the scarcity of appropriate people to train for system simulation teams. Policy-oriented research organizations in developing countries are often staffed by people with limited or weak backgrounds in quantitative areas. While some of these people can be trained to function as useful team members, it can be very difficult to locate people (within the policy research organization) who can effectively take leadership in model development. Recruitment of trainees with requisite qualifications from *outside* the policy research organization is clearly called for in these cases. There are, however, administrative obstacles here that vary from country to country. These must be dealt with if a viable, indigenous team is to develop.

Another fundamental problem that has emerged is that of retention. An effective system simulation team is a valuable asset that will be sought after by other government agencies and the private sector. It follows that there must be strong personal incentives to retain key team members. Competitive salaries are important; but, again, creative administration will probably be required to make this possible within the civil service structures of many developing countries. Another important factor which can enhance retention is personal interest in, and dedication to, the solution of the agricultural and rural problems of the society. Experience has shown that team members from strong rural backgrounds are much more likely than others to make long-term professional commitments to the goals of an agricultural policy research organization.

These problems of recruitment and retention also indicate that in many cases foreign consultants will be needed for some time as countries develop internal human resources. These foreign consultants must perform two important functions: they must ensure that the system simulation team is functioning effectively as part of the host country's decision-making process, and they must enhance movement toward the self-sufficiency of the indigenous team.

Conclusion

The personnel requirements of a system simulation team have been developed by analyzing the functions that must be carried out to effectively involve quantitative methods in the decision-making that guides agricultural sector development. These requirements are seen to be very demanding. Unique people from various disciplines are required who can work together effectively. These requirements are so demanding that for countries with few educated professionals, it may not be feasible to develop viable system simulation teams in the foreseeable future. In other countries the development of such teams is feasible, given careful selection of team members and equally careful planning of education and training programs for individual team members. Guidelines have been provided for designing degree and nondegree programs for individual team members. In most cases educational needs can be met by carefully designed degree programs; however, special nondegree programs can be important in certain cases.

In many countries foreign consultants will be needed in the short run to guide the development of the indigenous team and the contribution of the team to the host country's decision-making process. Unusual and creative administration is needed to ensure appropriate selection of team members and an environment that will encourage retention of key personnel.

FOOTNOTES

[1] Based upon U.S. standards.

[2] William A. Mehrens and Steven M. Downing, "Candidate Selection Procedures: Multinational Program of Study in Systems Analysis for Developmental Planning," Training Program Paper (East Lansing: Michigan State University, 16 April 1974).

PART TWO

A KOREAN AGRICULTURAL SECTOR CASE EXAMPLE

CHAPTER 6

DEVELOPMENT AND IMPLEMENTATION OF A PROJECT: KOREA

Francis C. Jones
Dong Min Kim
George E. Rossmiller

Background

The genesis of the Korean project[1] dates back to 1970, when the Korean government became interested in obtaining dollar loans for agricultural development projects from the United States Agency for International Development (AID). Until that time, AID investments in Korean agricultural development had been through the use of local (won) currencies generated through P.L. 480 programs. AID, while willing to consider dollar loans for agricultural development, at that time required that the selection of investment projects be based on comprehensive agricultural sector studies which delineated the major constraints to a country's agricultural development and provided a listing of investment priorities to remove those constraints. The two governments agreed to carry out a three-month study of the Korean agricultural sector and a contract was entered into with a U.S. institution.

The study was scheduled at a time when the Korean government was preparing its Third Five-Year Economic Development Plan (summer of 1970). At the request of the Ministry of Agriculture and Fisheries (MAF), contractor personnel devoted most of their time to advising and assisting in the preparation of specific parts of the agricultural portion of the Third Five-Year Plan. This was useful in itself, but did not provide the information and analysis needed by AID to justify agricultural sector or project loans.

Early in 1971, AID initiated discussions with the MAF relative to carrying out over a nine-month period a comprehensive agricultural sector study having two major objectives:

1. To provide the basis for an agricultural sector loan or agricultural project loans through identification of investment priorities for agricultural development

2. To provide a sound analytical base from which MAF could make improved planning, programming, and policy decisions

Apart from using agricultural sector analyses as a basis for agricultural sector loans, AID has had a much broader rationale for such studies. Sector studies are important to preserve and interrelate the results of specific studies and programs within the agricultural sector and to relate the agricultural sector to the rest of the economy. Thus, agricultural sector models are important in analyzing the interactions within the agricultural sector, as well as between the agricultural sector and the nonagricultural sector of the economy.

In supporting agricultural sector studies, AID can provide demonstration and support toward an institutionalized interest and capacity for greater analytical input to the planning and policy decision-making in a given country. This catalytic action can take several forms and perform several functions. The forms include provision of technical assistance, financial resources, and training. The functions include a focus of interest, an organizational, technical, and methodological ability, and in some cases initial entrée to the decision process at levels not achievable by indigenous technical personnel.

AID support of such studies, when they involve building an indigenous investigative capacity to help solve problems, can be provided only when a country's decision-makers have exhibited a will to improve their decision-making and investigative capacity. Even then, foreign assistance cannot provide the intimate knowledge of the indigenous situation, an understanding of existing institutions, the knowledge necessary to operate effectively in the local environment, or the linkages necessary for institutionalization and sustained optimum use of the investigative capacity. The foreign assistance will eventually phase out and the indigenous personnel and investigative units must be capable of independent operation at that point.

In spring, 1971, the Government of Korea and AID reached agreement that AID would finance a nine-month agricultural sector study. Michigan State University was approached by AID as the possible contractor for the study for two reasons: (1) The MSU role in successfully carrying out one of the most comprehensive agricultural sector studies undertaken up to that time--the Consortium for the Study of Nigerian Rural Development and (2) the MSU involvement in research and development work on a system simulation approach to planning agricultural development. Michigan State had just negotiated a follow-on Contract (number 2975) to the original systems simulation research Contract (number 1557) with the Technical Assistance Bureau of AID to further develop, test, adapt, and utilize the systems approach and simulation modeling techniques developed in Nigeria [3]. MSU was looking for a country with compatible and knowledgeable decision-makers concerned with agricultural sector development and which had at least the minimal prerequisites of a cadre of agriculturally trained personnel at the intermediate level and an institutional structure into which the MSU team could fit.

The Korean Ministry of Agriculture and Fisheries was interested in the sector study, not only as a basis for foreign assistance loans, but also to assist in establishing their own investment priorities for budget requests to the Economic Planning Board and ultimately to the National Assembly. General responsibility for the project was assigned to the Assistant Vice-Minister for Administration, who in turn designated the Agricultural Economics Research Institute, later renamed the National Agricultural Economics Research Institute (NAERI), as the operational counterpart agency for the project. NAERI was originally established in 1967 as a part of the Office of Rural Development (the technical agricultural research and extension agency of MAF) to provide farm management analysis and micro-economic input to the technical agricultural research program. In 1970, NAERI was removed from ORD and placed in MAF under the Vice-Minister to assist in national agricultural planning and policy analysis.

Contract negotiations were successfully completed between AID and MSU, and the Korean Agricultural Sector Study was begun in August, 1971. A comprehensive sector study report was completed in nine months [4] and combined the traditional pen, paper, and desk calculator exercise with the generalized system simulation approach developed by MSU in Nigeria. In addition, a more detialed study of the four main investment priority areas--land and water resource development, agricultural input and product marketing, and agricultural research--was completed during summer, 1972 [1]. The availability of software components from the Nigerian project which could be reassembled in ways applicable to Korean agriculture and the experience gained in that effort made it possible to assemble the necessary descriptive information about how the Korean agricultural sector is structured, operates, and responds to policy alternatives and to project the consequences of following alternative development strategies over a 15-year planning horizon. The reports and recommendations were completed in a shorter period of time and at a much lower cost than would have been possible if the study had been a 100-per-cent pen, paper, and desk calculator exercise.

The decision by Michigan State to develop a rudimentary model in connection with the Korean Agricultural Sector Study was not without risk. While MAF had agreed to early model development, it was withholding the decision to agree to a follow-on project involving full-model adaptation and development over a period of several years with the concomitant commitment of scarce Korean professional manpower and logistic support. This position by MAF was understandable, since at that time the general system simulation approach to agricultural sector analysis was (in the view of both MAF and AID) still in the experimental stage.

MSU had to make a decision during this period to proceed with model development on the assumption that the follow-on full-scale project would eventually be approved by the Government of Korea or to proceed on the basis that model development might have to be aborted in spring, 1972. The former would involve expending more MSU resources than the latter, with the risk of aborting midway and thus reducing the magnitude of complete and salvageable accomplishments. If the latter path were chosen, model objectives in the short run would be much more limited and all activities would be directed toward project closure. Thus, if a last-minute decision were made to proceed, the restart and redirection costs would be substantial. Fortunately, MSU chose to take the risk and proceeded on the assumption that MAF approval for the follow-on project would be forthcoming. MAF had indicated that if it were satisfied with the sector study, it would give such approval; and in late spring of 1972, having become convinced that MSU had a high capability to carry out agricultural sector analysis, it gave approval for further adaptation and development of the generalized model in Korea.

In doing so MAF and the Korean government indicated their realization that sector studies soon become obsolete--that new data and information become available and government policies change--and expressed their intention to equip Korea with a capacity for continuous assessment and analysis of its agricultural sector. Thus, a sector analysis capability was to be developed and institutionalized into the agricultural decision-making process, providing a continuing policy planning tool which would improve the capabilities of decision-makers in planning, policy formulation, and program and project development.

Development and Implementation of the Project

Rationale and Objectives

In summer, 1972, shortly after MAF had given approval for further adaptation and development of the KASS model in Korea, MAF and AID began discussions of AID assistance to MAF in establishing a modern planning system (including institutionalization of the KASS models) to promote timely, more sophisticated economic analysis for solving problems in the agricultural sector. AID's decision to provide additional assistance in the agricultural area was based on a number of considerations.

First, the analysis and conclusions of the Korean Agricultural Sector Study had convinced ROKG that serious deficiencies existed in this area and that ROKG had requested AID assistance. Quoting from the study [4]:

> Korea's agricultural economic intelligence system is weak. Ideally the agricultural economic intelligence system of a mixed economy such as Korea's should supply reliable data and analysis to both private and public decision-makers on prices, production, resource base, resource use, acreage, yields, etc. Shortcomings in Korean data tend to rise out of: (1) reliance on public operating agencies to produce data on their own operations and (2) failure to adequately staff and insulate governmental organizations supposedly independent of operating and administrative influences .... As a result of deficiencies in data, both public administrators and private entrepreneurs are less well informed about agriculture than required for effective public and private decision-making and administration. Korea's facilities for conducting analysis and research (on its agricultural development problems) are semideveloped, inadequately supported and poorly coordinated.

This recognition by ROKG was a desired outcome of the study when AID agreed to finance it. The study reinforced the concerns that were already evident in some Korean government quarters: Korea's agricultural statistics were in need of assistance. An apparent need existed for training personnel in agricultural economics, policy analysis, and program and project development, since at that time only 19 individuals out of a staff of 400 in MAF were trained in the agricultural economics area. ROKG, in requesting U.S. assistance, acknowledged the shortcomings in the current planning system and identified the U.S. as a suitable source for the assistance needed.

Second, the Government of Korea (ROKG) had recently recognized the importance of more balanced development between the agricultural and nonagricultural sectors of the economy and was increasing its emphasis on agriculture. In the Third Five-Year Plan (1972-1976) ROKG had projected an increase in central government investments in agriculture of about 60 per cent over the Second Five-Year Plan amounts, and the new "Sae-Maeul Movement" (New Community Development Movement) initiated in 1972 by President Chung Hee Park placed even greater emphasis on agriculture with a substantial increase in planned ROKG investment in agriculture over the original Third Five-Year Plan (TFYP). The First and Second Five-Year Economic Development Plans had concentrated on building a social infrastructure and establishing heavy and export industries. During this ten-year period agriculture had been purposely neglected in favor of a national development strategy stressing the industrial and urban sectors of the economy. This strategy had taken its toll on the agricultural sector. During the decade of the 1960's, the average annual growth rate of the total Korean economy was 8.2 per cent, while that for agriculture was 3.8 per cent. Such an agricultural growth rate is high, compared to agricultural growth rates in other countries, but low, relative to the demands placed upon Korean agriculture by markedly higher growth rates in the nonagricultural sector. It was believed that the implementation of a project to assist in establishing a modern planning system within MAF would make the increased allocation of resources into the sector more effective.

Third, assistance of this nature offered AID the opportunity to focus its efforts on an activity that would have a significant impact on future Korean agricultural development at a relatively low cost; i.e., it would be an efficient use of U.S. resources. Because the assistance was to be at the planning level, near the top of the organizational pyramid, the opportunity existed for developments, improvements, and changes to subsequently permeate and affect entire systems and organizations.

The project, named the Korean Agricultural Planning Project (KAPP), began in 1973 and became one of three interrelated components of the MAF/AID Agricultural Planning Project. These components were,

1. The ongoing MSU/Korean Agricultural Sector Study team (KASS), (the Korea field operations of the MSU Agricultural Sector Analysis and Simulation Project diagrammed in Figure 1), which was responsible for developing and helping to institutionalize the agricultural sector and subsector models

2. An American/Korean Agricultural Planning Project team (KAPP) which was responsible for assisting the MAF in establishing a modern planning system (including institutionalization of the KASS models) to promote timely, more sophisticated analysis for solving problems in the agricultural sector

3. A training component to educate Koreans in model development and in the disciplines required for effectively utilizing a modern planning system

MAF requested that Michigan State University be the contractor for the KAPP activity for the following stated reasons:

1. Michigan State University, through its participation in the Korean Agriculyural Sector Study and follow-up work with the simulation model in Korea, had a unique knowledge among American agricultural institutions of Korean agriculture and its problems

2. The agricultural sector simulation model with which MSU would continue to be associated would be an essential part of the Korean Agricultural Planning Project. Only MSU had experience in applying this type of model to individual country agricultural sectors

3. The imporance of having a Chief of Party of the Korean Agricultural Planning Project who thoroughly understood the simulation model's capabilities and needs for continual development

4. The performance of MSU in jointly carrying out the sector study with MAF

MSU accepted, and the Korean Agricultural Planning Project (KAPP) team became a separate, but related, field activity of the Agricultural Sector Analysis and Simulation Projects.

KAPP's Role in KASS Model Development and Institutionalization

While KASS was designed to be developed into an analytical backstopping unit with the capability of using large and complex computerized models for analysis of Korean agricultural development problems, KAPP was designed, in part, to help introduce the use of KASS models into the decision-making structure of MAF and to help MAF decision-makers identify and interpret their problems such that the KASS unit could help analyze and propose solutions to those problems. KAPP personnel, together with Korean decision-makers, recommend to the KASS team applications of the models and the development of new model components which will contribute to policy, program, and project analysis and development, and also supply data for the models. They help KASS in understanding priority policy and development questions that MAF has to deal with. Thus, KAPP provides interim linkage support between KASS and the decision-makers so crucial to the effectiveness of the investigative unit. To insure close cooperation and coordination between KASS and KAPP, a single MSU field project coordinator administers the foreign assistance operations of both units.

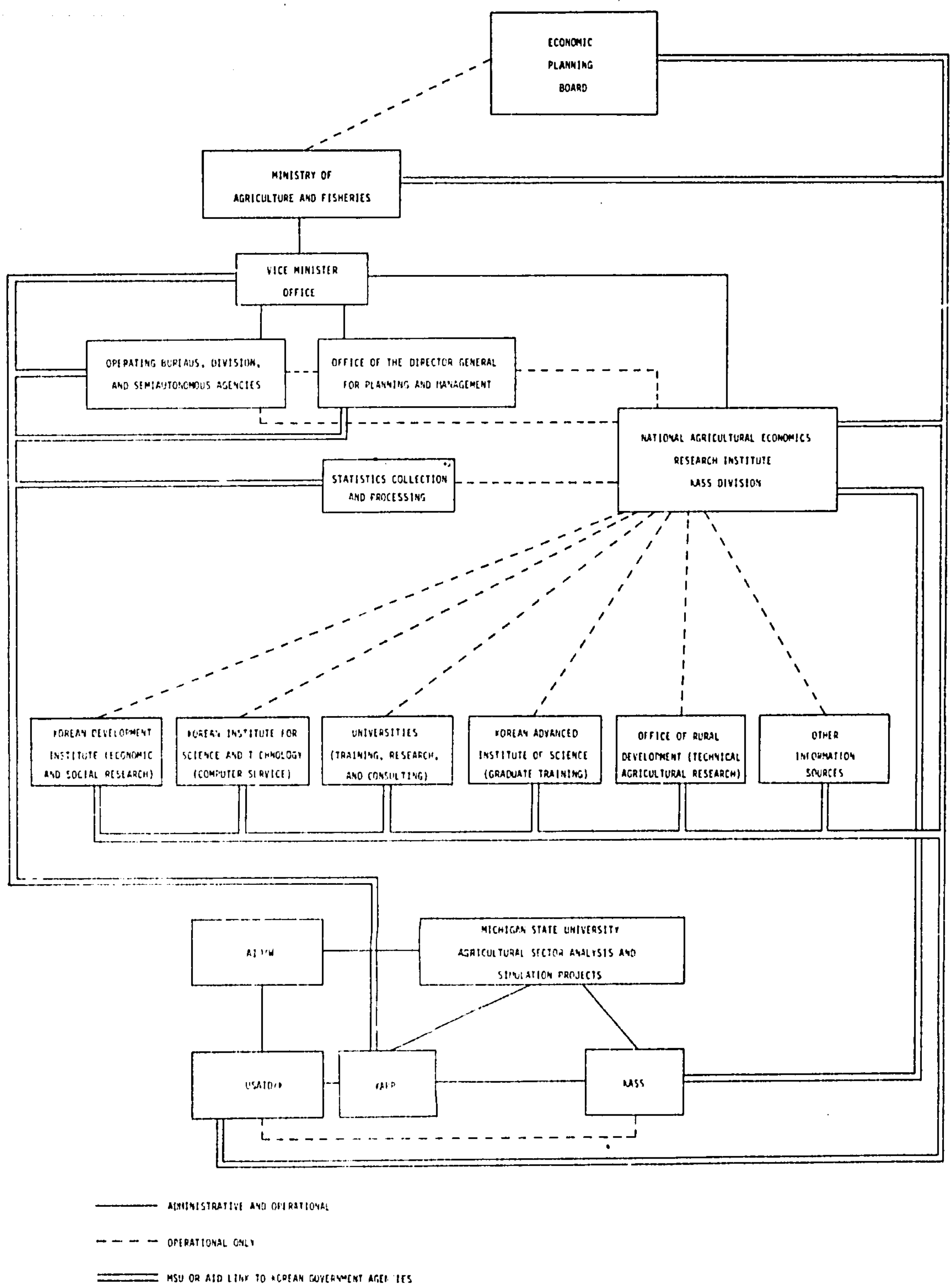
Figure 1 indicates the linkages between KASS and KAPP and the linkages of both of them with the relevant Korean agencies and with AID, as well as the established linkages of Korean institutions. It is obvious from the diagram that the AID and MSU activities are supportive of, and integrated with, but not substituting for, the indigenous institutional structure. The MSU and AID blocks and linkages can be withdrawn at any time, leaving the indigenous institutional structure and linkages intact and functioning. This project structure was designed by MAF/MSU/AID to insure that the survival of the investigative capacity being built in Korea would not depend upon MSU or AID remaining within the structure.

The KASS Project

The project began with the generalized system simulation approach to sector analysis being integrated with the traditional approach in the preparation of the Korean Agricultural Sector Study. Modeling efforts during this phase were tied to the requirements of the sector study team in meeting the nine-month deadline for producing its report. After completion of this phase in June, 1972, the KASS team[2] settled down to a more normal pace of model adaptation, testing, and development.

At the onset of the project it was anticipated that the majority of the work of developing the model would be completed by April, 1974, that Koreans would be trained to take over the systems science work, and that the MSU systems scientists could leave Korea then. It was also expected

FIGURE 1. MICHIGAN STATE UNIVERSITY PROJECTS' LINKAGES WITH AID AND KOREAN GOVERNMENT AGENCIES



that the institutionalization and utilization aspects of the project could be satisfactorily worked out so that the remaining members of the MSU team could leave by June, 1974 (the original termination date for Contract AID/csd-2975), with only short-term advisory services from MSU needed after that date. As events have shown, these judgments were much too optimistic. The difficulty in finding Koreans qualified for training in systems science to enable them to continue model development were misjudged, as was the length of time it would take the KASS team to attain a working model and for KASS and KAPP personnel to convince middle-level Korean decision-makers that the models could be useful to them in solving problems. Subsequently, the contract was extended to June, 1976, and provision was made for a MSU systems scientist to remain in Korea until December of 1977.

During the first three years of the project (1971-1974), the major efforts in Korea were directed at developing, testing, modifying, and finally attaining a working simulation model. Before questions of institutionalization and utilization could be seriously raised with Korean decision-makers, it had to be proven that models useful to them could in fact be developed. The MSU approach to sector analysis was as yet untried from the standpoint of a complete generalized model and relevant submodels. The situation was entirely different from introducing and gaining acceptance of, for example, input-output tables or linear programming. These can be shown to have been used with some success in the developed world. Not so the general system simulation approach.

The concentration on model development led some people to feel that MSU's interest was on systems science modeling per se and that it was not interested in institutionalization and utilization nor on the economic relationships and problem sets contained in the Korean agricultural sector. Later, as economic applications became possible, it still appeared to some observers that emphasis was on systems science modeling as the end and economic application as the means. There was a strong feeling that MSU needed to change emphasis to efficient economic modeling and analysis of the Korean agricultural sector. This view came about in part because of the large number of systems scientists on the MSU KASS team, including the leader replacing the agricultural economist who left the KASS team in June, 1973. What was not realized by these critics was that the foreign assistance component of the agricultural economic input required for successful institutionalization and utilization of the models was to be supplied mainly by the KAPP segment of the MAF/AID overall Korean Agricultural Planning Project and that MSU KAPP and KASS activities were to be closely coordinated by a single project leader.

In late 1973, when MSU could look ahead to an early attainment of a working model, it shifted the declared objective of the project from "research on the general, computerized, systems science, simulation approach" to "a project to increase the usefulness of developmental studies and analyses....through further development, testing, and application of the simulation approach and models." Thus, in 1974, when a working model had been attained and there was a product to "sell" to decision-makers, KASS, working with the KAPP group, shifted emphasis to model institutionalization and utilization. To successfully effect such a shift in Korea very likely would have been impossible without the complementarity of the KAPP project. The attainment of a working model also allowed development of model components to tie into and complement the sector model as specific needs were assessed through interaction among KASS/KAPP personnel and ROKG decision-makers.

Training

In 1971, at the inception of the project in Korea, the Agricultural Economics Research Institute (AERI), later renamed the National Agricultural Economics Research Institute (NAERI), had a strong farm management orientation and had not yet established itself as a capable, creditable policy analysis unit within the Ministry. In fact, AERI had only four people with advanced degrees in agricultural economics and none with degrees in systems science. The single holder of an advanced degree at the Ph.D. level was the director. His duties were primarily research, management, and administration. Thus, KASS began within a relatively new, untested policy analysis unit in a Ministry which only recently had recognized its need for improvement in the planning and policy formulation areas.

It was apparent from the beginning of the project that either substantial numbers of the NAERI staff needed additional training or that NAERI would need to recruit qualified personnel (1) to be able to take over further model development and to effectively use the models as analytical tools and (2) to become a useful investigative unit for MAF and other agencies of government charged with agricultural sector development. It is not enough to have a team of experts come into a country, build a model, and then turn it over to less-skilled indigenous personnel to operate. Models must undergo continuous development as new uses are found for them and a country's agricultural problems change. This requires recombinations of existing components and the development of new components, which in turn require highly trained people, including in the area of systems science. Because finding qualified candidates is difficult and because of constraints imposed on recruitment by the Korean civil service system, the only choice for NAERI was to train its own people;and MSU joined with AID in extensive training of NAERI personnel.

The long-range plan developed by NAERI for staffing NAERI/KASS with the critical systems scientists, agricultural economists, technical agriculturalists, and computer programmers capable of developing and utilizing models is shown in Table 1.

The table indicates the ideal staffing plan to be achieved at some point in the future, the staffing status as of March, 1976, and the planned status as of December, 1977. While the planned staff size by December, 1977, is only two professionals short of the ideal, the training level falls considerably short. For example, no systems scientists are staffed as of March, 1976; two are expected to complete training by December, 1977. This is still three short of the ideal staffing plan. Ten agricultural economists are staffed as of March, 1976, with one addition expected by December, 1977. This will be three more than the ideal but includes personnel trained at a much lower level than shown in the ideal plan. A similar situation is projected

Table 1. Long-Range NAERI/KASS Staffing Plan

Fields		Ideal	Present (as of March, 1976)	Planned (as of December, 1977)
Systems Science	Ph.D.	3 (1)	0	1 (1)
	M.S.	2	0	1
	B.S.	0	0	0
	Subtotal	5 (1)	0	2 (1)
Agricultural Economics	Ph.D.	5 (2)	2 (2)[a]	3 (2)
	M.S.	3	5[b]	5
	B.S.	0	3	3
	Subtotal	8 (2)	10 (2)	11 (2)
Technical Agriculture	Ph.D.	2 (2)	0	0
	M.S.	0	0	0
	B.S.	1	1	1
	Subtotal	3 (2)	1	1
Computer Programming	M.S.	2	0	1[c]
	B.S.	1	2	2
	Subtotal	3	2	3
Subtotal	Ph.D.	10 (5)	2 (2)	4 (3)
	M.S.	7	5	7
	B.S.	2	7	6
TOTAL		19 (5)	13 (2)	17 (3)

Notes:

1. ( ) is part-time positions included in total.
2. a. Both have participated in the Development Analysis Study Program at MSU.
   b. Three of five have participated in the Development Analysis Study Program at MSU.
   c. Participating in the Development Analysis Study Program at MSU.
3. Additional inputs will be necessary from the fields of technical agriculture, sociology, public administration, etc., through cooperative arrangements with ORD, MAF, universities, etc.

for the technical agriculture and computer programming staffs. Technica agricultural help is available on contract from the universities and from the Office of Rural Development. NAERI recognizes the importance of input from a variety of other disciplines, such as sociology and public administration, to model development and plans to obtain help in these areas through cooperative arrangements with appropriate Korean universities.

With one exception, training began in 1973,[3] and by 1977 a total of 45 Koreans will have been trained in the following areas under the Korean Agricultural Planning Project:

Agricultural, project, program, and policy planning and resource allocation	17
Marketing	11
Outlook	7
Systems science	5
Agricultural administration	3
Statistics	2

There also have been observation tours lasting about four weeks each for top- and middle-level administrator from MAF to see at first hand how modern planning systems and analytical capabilities are institutionalized and utilized in the U.S.

Of the above 45 Koreans trained in the listed areas, 17 received training in areas directly related to model development and operation. Not all of the 17 have returned to the NAERI/KASS unit; some have been placed within the Ministry proper. This training program has been, and will be, increasingly beneficial to the project because those trained are changing the "climate" within MAF towards more sophisticated analytical work and planning.

During the period from 1972-1974, NAERI at any given time had from one-fourth to one-third of its professional staff away for training[4] without any adjustment in their work load. Model development and utilization and training of personnel were conflicting activities.

It was initially thought that people with a good basic training in agricultural economics and statistics could be trained over a period of 9 to 12 months in systems science and then, after several months of in-service training with the MSU systems scientists, would be capable of taking over model development work. Thus, in July of 1972, a Korean was sent to the Asian Institute of Technology (AIT) in Bangkok for a nine-month diploma course in systems science; and in September, 1973, MSU initiated a 12-month training program oriented toward systems science, computer science, and economics (Development Analysis Study Program) to produce professionals who could develop and apply decision-making models at project, program, and policy levels. The project scheduled six Koreans to complete this program, either as nondegree training or as part of a graduate degree. However, experience has shown that neither the AIT program nor the MSU Development Analysis Study Program by itself produces people who can carry out model development work on their own.

When this became evident in early 1974, a search was begun for one or more MAF or NAERI employees who had the basic training, capability, and desire to complete a Ph.D. program in systems science. While no one was found who seemed certain to complete the Ph.D., it appeared that two of the candidates might have potential. AID agreed to finance both of these candidates for the one-year MSU Development Analysis Study Program, with the possibility of their continuing in a Ph.D. program in systems science, provided they proved capable. Unfortunately, although one student completed a systems science M.S. program, neither student continued in the Ph.D. program.

In spring, 1975, a search was begun for a possible candidate outside of MAF and NAERI. This was a course of last resort, since it could not be guaranteed that an "outsider" would eventually return to NAERI and work as a full-time member of the KASS team. A person was located at the Korean Institute of Science and Technology (KIST) who had the proper qualifications. A leave of absence was arranged from KIST for two years for him to complete course work at MSU leading to a Ph.D. in systems science. He would return to Korea to do his thesis research at NAERI and then continue to work for NAERI/KASS half time. MSU systems science support to NAERI/KASS was extended until December of 1977 to maintain continuity.

NAERI will not meet the staffing goal for two full-time Ph.D. systems scientists in the foreseeable future. It is clear, however, that they will have one systems scientist trained at the M.S. level working full time and one at the Ph.D. level.

Agricultural Economics

Four Ph.D.'s, two having systems science training, are serving with NAERI on a part-time basis. Two of these are working with NAERI/KASS. One person is studying for the Ph.D. and will return to NAERI full time in August, 1977. He has had systems science training and will serve as the KASS team econometrician.

Five people earned an M.S. degree, three of whom have taken the Development Analysis Study Program and are serving with NAERI full time. Three people with B.S. degrees are serving with NAERI full time. Of the total KASS/NAERI staff of agricultural economists, six attended the MSU Development Analysis Study Program.

Computer Programmers

Two programmers are working full time, compared with a planned staffing of three full-time people. One computer programmer is in training for the planned M.S. position for December, 1977. Additional efforts need to be made in recruiting programmers with experience in programming various kinds of agricultural sector models and quantitative techniques (simulation models, linear programming models, regression analysis, etc.). Recruitment of qualified programmers into government is difficult at best because of the sharply increasing demand for programmers from the higher-salaried private business sector. In the meantime NAERI has supplemented its computer programmer capacity by contracting for well-trained, experienced programmers from KIST for specific assignments (e.g., programming the national economy component).

Organizational Structure

The contract between MSU and AID for the initial nine-month agricultural sector study provided for a separate report on the organization of the Ministry of Agriculture and Fisheries and the organizational and functional constraints to effective planning and policy development in MAF [2]. This study was included because both MAF and AID recognized that the then-present MAF planning and administrative organizational structure might serve as a deterrent to the effective implementation of recommendations on policy, program, and project changes coming out of the sector study. At the same time, the organization study was to cover ways of improving the MAF planning system, to include data collection and processing, statistical and economic analysis, and policy, program, and project formulation. Thus, from the outset an important part of the activity in Korea was institutionalizing an improved investigative capacity for providing decision-makers with better information and analyses on which to base choices of policies, programs, and projects.

In connection with institutionalizing an investigative capacity for agricultural development planning, the sector study team found that the then-current MAF organization provided little incentive and, in some cases, little opportunity for MAF decision-makers to absorb and utilize centralized investigative input to the planning and policy process. Little horizontal or vertical coordination was found between MAF agencies as planning decisions were made. Bureau directors had a great deal of autonomy from higher administrative authority. MAF was organized totally along commodity lines, with no concession to function; thus, systematic planning was difficult. Decision-makers often had short tenure in their positions, thus creating a lack of memory and experience. NAERI was more often used by top-level policy-makers than by the bureaus which do much of the preliminary planning for MAF.

The above findings led to recommendations in the organization report submitted to MAF in June, 1972, for organizational changes in the MAF planning system toward an increased planning and policy development capacity in agricultural policy analysis, agricultural outlook, agricultural program and project evaluation, agricultural statistics--including data collection, processing. and utilization. The following recommendations were made:

1. That a Plans Coordination Unit be established with staff responsibilities administratively under the Planning Coordinator

2. That the planning units located in the various bureaus and divisions remain under the administrative control of their respective units but be physically consolidated and housed near the office of the responsible Assistant Vice-Minister

3. That an economic research unit be established for which the primary function would be basic long-run analysis of the Korean agricultural economy. The research unit should be either an independent institute, like the Korean Development Institute (KDI), or a major section of KDI. It should not be expected to spend its time doing short-run analysis for MAF officials for planning and program review purposes. The structural analysis--e.g., micro production economic studies of farm, marketing, and input firms; price and demand analysis; and macro supply and demand studies--would furnish the basic material upon which both effective outlook and sector analysis could be built

4. That a single coordinated Economic Outlook Unit be established having the responsibility for all such work formerly scattered throughout MAF and its affiliated agencies

5. That a Policy Analysis Unit be established as a separate unit, but closely related to the economic outlook unit, to provide the Minister and Vice-Minister with economic analysis of various policy proposals, and to evaluate economic implications of plans made by the various Bureaus and Divisions

6. That a Statistical Unit be established under a Coordinator of Statistics and be put under the same administrative direction as the Policy Analysis and Outlook Units

7. That the Agricultural Economics Research Institute (now NAERI) be renamed the Institute for Agricultural Economics and Statistics (IAES) and be headed by a Director at the Assistant Vice-Minister level. The Policy Analysis Unit, Outlook Unit, and Statistical Unit would come under his administrative control

MAF, in fall, 1972, attempted to gain ROK government approval for implementing recommendation numbers 4, 5, 6 and 7 above but was unable to do so because the proposal would have added one Assistant Vice-Minister and two Bureaus to the MAF structure. This would have placed the number of Assistant Vice-Ministers and Bureaus in MAF above the maximum permitted for government ministries. The only solution at the time would have been to downgrade the Director of the proposed Institute for Agricultural Economics and Statistics to bureau-level status and the Coordinators of the Economic and Statistics Units to division-level status, which would have caused unacceptable inequities within the system.

Following this adverse decision, MAF decided to wait until after the KAPP team had been in Korea long enough to familiarize themselves with the problem and to prepare their own recommendations on MAF organization. In the words of a high MAF official at the time, "Foreign advisors should go through a painstaking orientation. And only after having familiarized themselves with the different culture and situation can they make suitable recommendations." This is particularly true of recommendations dealing with institutional change or plans and policies having to do with distribution of ownership of resources or power.

In fall, 1972, it was expected that the KAPP team would be functional by mid-1973. Unforeseen delays were encountered in project approval and funding and the team did not begin to arrive until summer, 1974. After going through the "painstaking orientation," the team was expected to prepare the MAF reorganization plan. The team decided that the plan should be a product of interaction and seminars with MAF and other government officials and that it should be an ongoing activity for at least the duration of the KAPP contract. Some reorganization along the general lines indicated above has been accomplished. Additional changes are crucial to the full institutionalization of the KASS investigative capacity. Solving the institutional and organizational problems is difficult because of the rapid turnover of MAF administrators. Frequent personnel changes present a problem not only in the final institutionalization of the KASS investigative capacity but perhaps also in the continuity of its utilization by decision-makers.

Following the completion of the initial sector study in the summer of 1972, attention of the KASS team turned mainly to model development until spring, 1974. During this period some efforts were made to strengthen linkages with relevant indigenous institutions and interactions with decision-makers on model conceptualization took place,[5] but major institutionalization questions were not addressed to any significant degree. Two changes, however, took place in December, 1973, which improved the internal organizational environment of the KASS team. First, the Agricultural Economics Research Institute was reorganized into the National Agricultural Economics Research Institute. This change in name recognized the broader role being carried out by this agency after its removal from the Office of Rural Development in 1970 and its increasing involvement in the planning and policy analysis functions in MAF. Second, during this reorganization a new division, the Agricultural Sector Analysis Division was created in NAERI with responsibility for carrying out the KASS team activities. Thus, the KASS activity was upgraded to permanent division status from its earlier temporary task force existence.

Referring to Figure 1 concerning the investigative unit in the decision structure, in the Korean case the basic administrative and structural linkages already existed with NAERI before the KASS project began. KASS was attached to NAERI as the Korean counterpart institution and was able to take advantage of this existing set of linkages, even though they were incomplete and in some cases weak. Incomplete linkages included those to computer services and to the research, training, and consulting services of universities and other research and training institutions.

Computer services were difficult to obtain. The first attempt was to use the computer services provided by the Government Computer Center, an installation operated by the government to provide services free to government agencies. This computer installation is administered as a data processing center, with priority given to large data processing jobs, such as survey tabulation or census data processing. The needs of model developers and researchers are not met. At times job turn-around time was once a week, when a minimum of three times a day would have been more appropriate. This "free" service resulted in ineffective use of KASS team time and in inefficient model development and operation. It was finally arranged for the KASS team to use the computer installation at the Korean Institute for Science and Technology (KIST) on a pay basis, with AID and NAERI sharing the cost of the service. The agreement specified that Korean resources be used for operational activities and AID resources be provided for model development activities. Over time, as the emphasis on model development declines and as operations increase, the Korean Government provides an increasing share of the computer service cost.

Another serious difficulty faced by NAERI was the fact that it is under Civil Service regulations for personnel salaries. Government salaries are approximately one-half those which can be expected in a university and one-third to one-fourth those which can be expected in business. Further, individual opportunities and payoffs are greater in governmental administration than in government agency research. Thus, there is always pressure on NAERI personnel to move out of the institute for personal advantage. In addition, recruitment and retention of new, highly trained personnel are extremently difficult.

To facilitate institutionalization and make it effective, changes must be made in organizational structure and decision-makers must understand the simple rudiments of the investigative procedures, in this case the systems simulation models, and their uses. In most cases, a change in decision-maker attitudes towards the use of sophisticated investigative procedures is required. In the case of Korea this needs to be done at the highest levels of government, as well as at the sub-agency levels. In this connection, in Korea, the AID role was crucial. Its stature in Korea was such that it could gain access to high-level officials to present the case for these needed changes in a way not available to Korean and American project personnel.

In spring, 1975, the opportunity arose through AID auspices to brief the Deputy Prime Minister (also Minister of the Economic Planning Board) and the Minister of Agriculture and Fisheries on progress in model development and utilization, future potentials of the models in helping decision-makers, and problems of institutionalizing the models and breaking the government salary barriers in order to attract and hold qualified scientists. In addition. a seminar was held for senior MAF officials on the use and development of the models. This seminar stressed that successful institutionalization of the NAERI/KASS activity would depend on NAERI and MAF decision-makers working together so closely that the models would eventually belong more to the rest of MAF than to NAERI. It was further stressed that while the work of making a model is complex and requires highly specialized skills, it is not true that decision- and policy-makers and other civil servants cannot understand, use, contribute to, and indeed, control the use and development of the models. Agricultural economists and systems scientists should be forced to explain their models. Decision-makers should insist that the models deal with Korea's problems and that they pass the tests for credibility (coherence, correspondence, clarity, workability) discussed in Chapter 1.

In summary, the amount of time required for successful institutionalization of an investigative capacity was seriously underestimated at the beginning of the Korean project. The amount and phasing of training, the conflict between training and operational work, the time required for model development to the point that trained Koreans could take over further development, and the slowness of the process of building linkages with support and service agencies and decision-makers were all underestimated. Much time and effort required for institutionalization had to be used for nonmodel analysts becoming familiar and experienced with the models, understanding what the models could and could not do, and in learning to use the model output with judgment and with other sources of information to analyze specific problems. Much time was also necessary for interaction and iteration with decision-makers on specific problem solutions to insure that the preconditions to an optimum problem solution were met.

A contract mechanism established within the Korean government in 1975 provides for government agencies to contract the services of a limited number of personnel from universities or other nongovernmental agencies on a project basis, either full or part time, and allows the government to provide a competitive salary. This means has been used to upgrade work quality at NAERI.

During the past few years concentrated efforts by KASS personnel have strengthened and made more firm the crucial linkages with other Korean governmental and nongovernmental institutions. Informal working relationships with action agencies in MAF and other government units, research institutes, and universities are being improved and extended through the establishment of problem-oriented task forces. A grain policy task force was created in summer, 1974, to work initially on very short-term grain policy issues confronted by the Korean government. Pleased with of the results of this work, MAF requested that the task force remain intact for work on additional short-term and longer-term grain policy issues. Later a task force was constituted to provide MAF analysis and input into the development of the Fourth Five-Year Economic Development Plan. Thus, the task force concept has been introduced and appears viable as an institutional construct for problem-solving in the Korean environment.

Perhaps one of the most difficult remaining problems is the location, both within the MAF organization and physically, of NAERI and its KASS analytical unit. NAERI is an institute of the Ministry of Agriculture and Fisheries and as such is not considered a part of MAF proper. This reduces its direct role with MAF action agencies in providing analytical input into the decision-making process. It is physically located outside of the Ministry building, which also tends to add to its isolation.

The spring, 1975, briefings and seminars with high-level Korean government officials generated a great deal of interest and discussion at the highest levels of the Korean government on the future of NAERI and its KASS models. However, a difference of opinion developed and the matter is quiescent at this writing. One group felt that NAERI should be incorporated into the Korean Development Institute (KDI), which carries out long-term economic and social research and policy analysis for the Government of Korea, resulting in more effective utilization of resources through joint use of facilities and research materials and better coordination between sectoral economists. This would also solve the salary problem, since KDI is authorized to pay salaries competitive with, or higher than, university salaries. A second group, which included most of the agriculturalists, felt that successful short-term economic and policy analysis of agricultural problems requires close interaction between the analysts and the decision-makers in MAF and ready access to

MAF data by the analysts. In their view, interaction and access to data would be seriously curtailed if NAERI were a part of KDI. There also would be a tendency for "KDI-NAERI" to emphasize long-term research at the expense of the short-term analyses needed by MAF decision-makers.

It is difficult to predict the exact way in which the investigative capacity of KASS will ultimately become institutionalized into the Korean governmental structure. One possibility would be to make the models available to both KDI and MAF and transfer the NAERI/KASS personnel to a properly institutionalized unit in MAF. This transfer would enhance the communication between KASS and the decision-makers, as well as the utilization of the models for problem-solving.

The ultimate solution to this issue, however, must of necessity be a uniquely Korean solution. But whatever the solution, it must permit close interaction between the investigators and the decision-makers in MAF and ready access to MAF data. The increased commitment to the kind of output provided by the KASS unit, the increased training activity, and the increasing demands being placed upon the unit by a wide array of government decision-makers are certainly encouraging signs. It is obvious that NAERI must remain flexible in its staffing and organizational structure in order to be able to respond to the wide array of decision-maker requests for their analytical input to the planning and implementation of agricultural sector development.

It is unfortunate that the main perspective of the Korean project tended to center on the KASS models. The written objectives of the MSU-AID contract focused on model development, testing, and application. The attention of interested people, both inside and outside of Korea, tended to focus on the models. Project staff tended to put dominant emphasis on the models in their discussions. Admittedly, the models were an important component of the project. However, when viewed from an institution-building perspective, the truly critical aspect was the development of the investigative unit with a cadre of trained personnel capable of using, adapting, and further developing the models as a tool in analyzing a wide variety of planning and policy problems. The most complex and challenging dimension of this process was the institutionalization of the investigative unit into the decision-making structure, with appropriate linkages to decision-makers and to support and service agencies.

Project staff were often asked, "When will the job in Korea be finished?", "When will the model be completed?", "When will you finish the final report and wind up the operation?" The answer to all these questions was, "*If we are successful, never.*" Once the KASS investigative unit is fully institutionalized into the decision structure, it must continue to be relevant and useful to decision-makers to remain an effective part of that institutional structure. It must continually adapt, update, and develop its analytical tools and models as the agricultural system they represent changes. It must continue to adjust its abilities to accommodate the changing nature of the problems confronting the decision-makers. Thus, the job is never completed and a "final report" is not an objective.

By the time the MSU projects will have phased out, a small but important core of Korean personnel (professionals directly associated with the projects) will have returned from training in agricultural economics and systems science. It is their task to take over the operation of the investigative unit and to insure its smooth and effective functioning. However well trained, these professionals will still be relatively inexperienced and will most likely need occasional outside support through short-term consultation.

The conviction by the MSU Agricultural Sector Analysis and Simulation Project team that an indigenous analytical capacity can be institutionalized within the decision structure of a developing country capable of using the general system simulation approach to produce analytical input to planning and policy decisions for agricultural sector development is on the verge of realization in Korea. This undoubtedly would not have been the case without the establishment of the KAPP activity which provided the crucial link as the mechanism for KASS team interaction with decision-makers and their problems. This linkage should be firmly established before the MSU contingent totally withdraws in December, 1977.

CHAPTER 7

AGRICULTURAL SECTOR MODEL CONCEPTUALIZATION: THE KOREAN EXAMPLE

Tom W. Carroll
George E. Rossmiller

In this chapter we will present a brief description of the physical characteristics, the socio-economic structure, and the institutional setting of the Korean agricultural sector. We will then present an overview of (1) the perspective and values held by the Korean decision-makers with respect to the agricultural sector and its relation to the national economy; (2) the general set of problems which has determined the scope of the sector analyses and sector modeling effort reported earlier in the Korean Agricultural Sector Study (1972) [1] and updated in the following chapters; (3) the current broad design of the Korean Agricultural Sector Model (KASM) in terms of its disaggregation levels, components, and linkages; and (4) the broad policy areas addressable by the sector model.

The Korean Agricultural Sector

The Republic of Korea is a peninsula in the temperate climate zone, bordered on the west by the Yellow Sea, on the east by the East Sea, or Sea of Japan, and to the north at roughly the Thirty-Eighth Parallel by the People's Democratic Republic of Korea. Seoul, the capital city in the northwestern part of the country, is at approximately the same latitude as Washington, D.C., and Lisbon, Portugal.

Of the 9.8 million hectares of land area, approximately 24 per cent, or 2.4 million hectares, is cultivated. About 70 per cent of the total land area is mountainous. Of the 2.4 million cultivated hectares, about half, or 1.2 million hectares, is paddy land suitable for production of the principal crop, rice. Approximately 80 per cent of the paddy land is irrigated.

In roughly the southern four provinces, a winter crop, primarily barley, is produced as a second crop on the paddy land. Upland crops are many and varied, including barley, wheat, and other grains and oil seeds; fruits, including the tree fruits--apples and pears and, on the southernmost island, oranges; vegetables, the most prevalent of which are Chinese cabbage, red peppers, garlic, and radishes; pulses, potatoes, both sweet and white; tobacco; mulberry, for sericulture; and ginseng. Vegetables are grown in plastic greenhouses on paddy land in winter, particularly near major cities.

Korea has experienced phenomenal economic growth since initiation of the First Five-Year Economic Development Plan in 1962. During the First Five-Year Plan period (1962-1967), average annual real growth rate for the total economy (including agriculture) was 7.8 per cent, while the rate for agriculture alone was 5.3 per cent. During the second plan period (1968-1971), the average annual total economy growth rate was 10.5 per cent, while the agriculture rate was 2.5 per cent. In the third plan period the comparable figures are 9.4 per cent and 4.9 per cent, respectively. Thus, while the agricultural sector performance was quite respectable relative to agricultural sector growth rates in other developing, or for that matter developed, countries, it lagged behind the total economic growth rate appreciably. Rapid farm-nonfarm migration during the last two plan periods softened the impact of this gap on a per capita basis; but by the third plan period, it was obvious to the government that further widening of the gap would be both economically and politically harmful. Thus, heavier emphasis and investment was programmed for the agricultural sector in the Third Five-Year Plan.

The Korean farm unit averages about one hectare in size, with about one-third of the farm households having less than .5 hectare, one-third between .5 and 1 hectare, and one-third more than 1 hectare. Relatively few farms exceed 3 hectares, the legal limit on cultivated farm size. Human and draft animal power are the main sources of energy, but mechanization in the form of 10 to 12 horsepower tiller and attachments is increasing. Institutional credit and modern inputs are supplied mainly through the National Agricultural Cooperative Federation, a semi-autonomous agency of the Ministry of Agriculture and Fisheries. This institution is also a major market channel, particularly for rice and barley, as it both markets on its own and handles government purchases for use, stockpiling, and price support activities.

The total population of Korean in 1975 was about 34 million people--45 per cent in the farm population and 55 per cent in the nonfarm population. The population growth rate is about 1.7 per cent per year; and through farm to nonfarm migration, the farm population has declined absolutely since about 1967. This creates strong pressures away from subsistency production and toward commercialization for farm households. It also suggests the need for farm size to increase and for labor-saving mechanization as the agricultural labor supply declines and as labor wages rise.

With rising real incomes, both farm and nonfarm, demand for food has increased rapidly. Per capita consumption of both rice and wheat has continued to increase, as well as consumption of fruits, vegetables, meat, and dairy products. Scarce foreign exchange is required for importation of rice, wheat, and feed grain. Grain imports have increased from about 700,000 metric tons in the mid-1960s to approximately 3 million metric tons in the mid-1970s.

Domestic production has also increased. Growth of total crop production over the last decade has averaged 2.5 per cent annually, with rice production increasing 1.5 per cent annually. Total grain production has remained fairly constant at about 7.3 million metric tons in recent years, due to a decline in barley and wheat hectarage. Fruit and vegetable production has increased at an annual rate of about 10 per cent, while livestock production has increased about 6 per cent per year in recent years.

To attain the increases in domestic agricultural production, both innovation of yield-increasing technologies and cultivated land-area expansion projects have been used. The Agricultural Development Corporation, a semiautonomous agency of MAF, is responsible for the design and implementation of all agricultural land and water development activities in Korea. These activities include upland development, tideland reclamation, irrigation, drainage, and paddy rearrangement and consolidation. The Office of Rural Development, an agency of MAF, has responsibility for technical agricultural research and extension. Research and extension efforts have concentrated on increased agricultural production, with primary emphasis on grains.

The continuing question facing Korean agricultural sector planners and policy decision-makers is how to use the resources available to achieve an optimum growth rate and pattern in the agricultural sector as an integral part of, and contributor to, the development of the total economy. To accomplish this task required an increase in the investigative capacity dealing with the agricultural sector and interacting with agricultural administrators and executives responsible for agricultural sector development decision-making. In 1971 the Michigan State University Agricultural Sector Analysis and Simulation Project team was contracted to work with the National Agricultural Economic Research Institute in the Korean Ministry of Agriculture and Fisheries to help strengthen that investigative capacity, based on a comprehensive system simulation model of the Korean agricultural sector.

Decision-Maker Perspectives on the Agricultural Sector

The beginning point in the Korean sector modeling and analysis activity was to determine the broad national values held by Korean decision-makers with respect to Korean agricultural development. These values were not explicitly stated by Korean decision-makers; nevertheless, "revealed preferences" could be found in the existing policies, in discussions with policy-makers about their current problems, issues, and concerns, in preference patterns of consumption and production among farmers and in the general political environment. The various national values were judged to cluster in four main categories:

1. Achieving improved food supplies, both quantitatively and qualitatively, preferably from domestic sources

2. Realizing a higher quality of life in rural Korea[1]

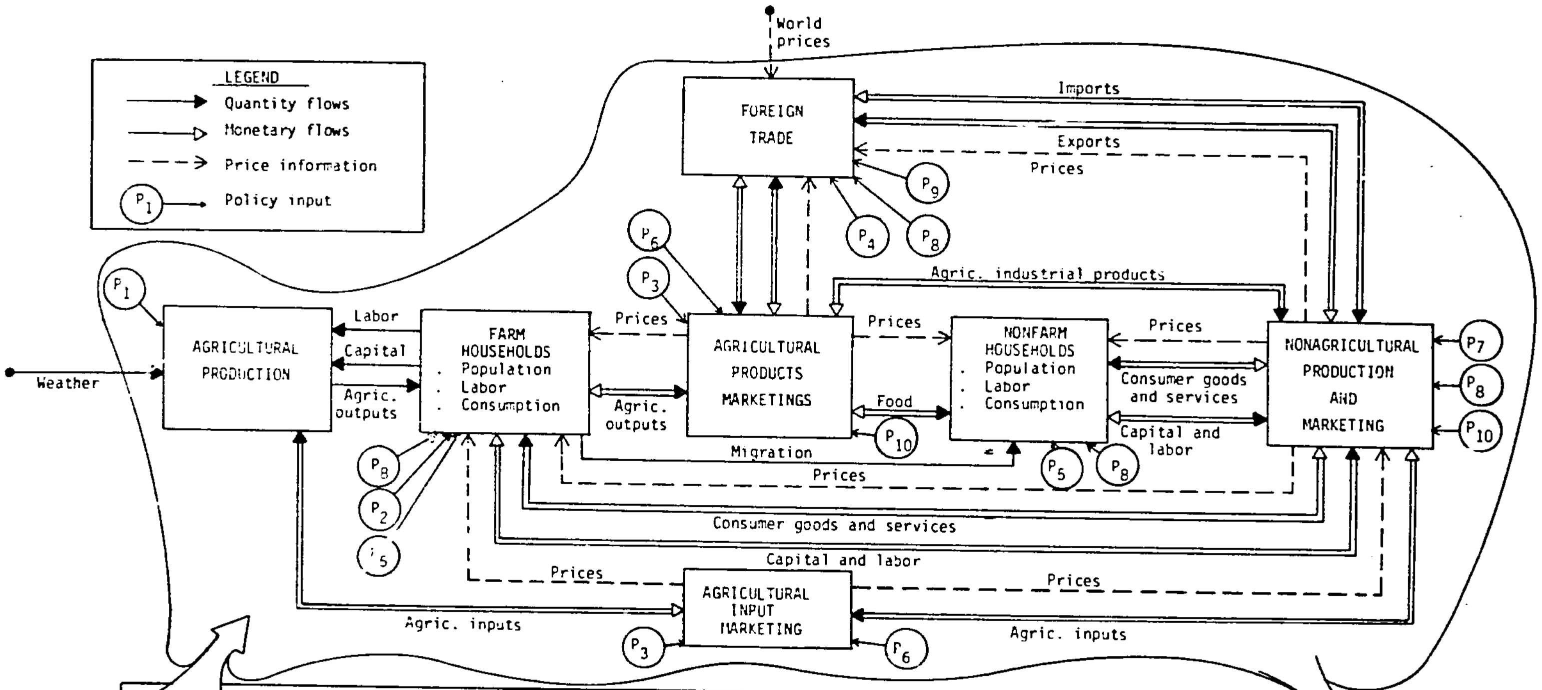
3. Enhancing and improving the contributions from the agricultural sector to the overall development of Korea

4. Improving administrative and political processes affecting Korean agricultural development

The structural and operational perspective of agricultural decision-makers toward the agricultural sector and its relation to the rest of the Korean economy is presented in Figure 1. The two main exogenous factors which influence the performance of the system from the "environment" are the weather and the world prices for agricultural commodity imports and exports and imported raw materials and manufactured products used as inputs to agriculture (e.g., fuel, fertilizer, machinery, etc.). The behavioral decision units within the system are divided into farm households and nonfarm households, with the associated respective economic activities of agricultural production and nonagricultural production and marketing. Operating at the interface between the agricultural sector and nonagricultural sectors are the foreign trade activities, agricultural product marketing activities, and the agricultural input marketing activities.

Figure 1 also indicates the major flows of commodities, inputs, capital, labor, money, and price information among the sectors. The agricultural marketing system channels farm products directly to consumers or to the agricultural processing industries. The foreign trade

FIGURE 1. AN AGRICULTURAL SECTOR PERSPECTIVE OF THE KOREAN ECONOMY



POLICY INSTRUMENTS

- P_1 Agricultural development--land, water, infrastructure, crop improvement, mechanization
- P_2 Agricultural credit
- P_3 Price controls and subsidies
- P_4 Import/export controls and subsidies
- P_5 Population control, health and welfare
- P_6 Market improvement
- P_7 Rural industrialization
- P_8 Tax rates--income, indirect, customs, etc.
- P_9 Monetary--interest rates, foreign exchange rates
- P_{10} Public consumption and investment

PERFORMANCE INDICATORS

GDP--total, per capital; nominal, real; agric., nonagric.; growth rate
Income--total, per capita; nominal, real; agric., nonagric.; farm, nonfarm
Trade balance--exports, imports; agric., related nonagric.
Nutrition
Employment
Tax revenues
Value added
Capital formation
Population
Special accounts status--e.g., GMSA
Inflation

sector exports Korean products to world markets and imports agricultural products to make up food deficits. Farm households are a net supplier of capital, labor, and migrants to the nonfarm sectors. The major inputs to the agricultural sector from the urban industrial sector include four basic products required to raise the level of agricultural technology: chemicals to control pests and diseases, fertilizer, farm machinery, and fuel.

The flows and activities outlined above are controlled by the internal domestic prices, the influence of world price, and the government fiscal, monetary, regulatory, and investment policies. These government "policy instruments" include (P_1) agricultural research and development programs and projects in land, water, infrastructure, crop improvement, mechanization; (P_2) agricultural credit;(P_3) price control and subsidies; (P_4) import/export controls and subsidies;(P_5) population control, health, and welfare; (P_6) market improvement; (P_7) rural industrialization; (P_8) tax rates--income, indirect, customs, etc.; (P_9) monetary--interest rates, foreign exchange rates; and (P_{10}) public consumption and investment in marketing facilities and nonagricultural production related to the agricultural sector.

"Performance indicators" are monitored by policy-planners and decision-makers to see if the system is "on course" in reaching desired goals. At the national level these performance indicators include gross domestic product (total, per capita; nominal, real; agricultural and nonagricultural; growth rate); income (total, per capita; nominal, real; farm household and nonfarm household); trade balances; nutritional levels, employment levels; tax revenues; value added; capital formation;

population levels and growth rates, including off-farm migration rates; status of special accounts (e.g., grain management and fertilizer); inflation rates; as well as other variables of interest.

The choice of strategies or policy sets and the goals themselves are determined by the political/administrative process. Formal planning exercises, which are carried out by policy-planning staffs, provide key inputs to the political/administrative decision-making process.

The Korean Agricultural Sector and Its Problem Set

At least three perspectives have influenced the design of the Korean agricultural sector model (KASM) since modeling activity started on a small scale in 1971. These may be identified as (1) the Korean perspective, which focuses on substantive agricultural issues and problems identified earlier under the first three value clusters related to improved food supplies, rural development, and agricultural sector contribution to national development; (2) the Korean perspective, which is concerned with improving the administrative and political processes affecting agricultural development (the fourth value cluster identified earlier); and, finally, (3) the MSU perspective, which is concerned with "adapting and testing of agricultural simulation models to sector analysis," a generalized approach concerned not only with developing models for Korea but contributing to the development of a general "software library" of models and components, training packages, and institutional linkages to expedite application of the approach in other settings. Let us discuss these three perspectives and their influence on the evolving sector model design in more detail.

Korean Perspective:
Agricultural Sector Development

The design of the sector model should reflect the concerns of agricultural decision-makers regarding the significant, substantive problems of agricultural development over the next ten to 15 years.

Improved Food Supply. The chief concern of Korean decision-makers is for Korea to domestically produce sufficient food to meet the effective demand from a growing population with rising per capita incomes to minimize expenditure of scarce foreign exchange on food and feed imports. To confront the set of problems inferred in this concern, a sector model must be disaggregated to a level at which it can address the important questions related to the production and consumption of livestock products (with their associated consumption of food grains).

While it is estimated that Korea must expand food production by 50 per cent between 1970 and 1985, it is also estimated that there must be a 250-per-cent expansion in food processing and market services during this same period to handle the rapidly changing shift in the population balance between farm households and nonfarm households. The model was designed to estimate the magnitude of the shift and, thus, the demand for food processing and marketing services; but it does not actually model these subsectors in detail in its current state.

Rural Development. Korean decision-makers are concerned with the impact of agricultural development policies on improving the quality of rural life, both absolutely and relatively with respect to urban life. Thus, decision-maker concerns with income and infrastructure questions had to be addressed by the sector model. All versions of the model have included provisions for disaggregation of the population into farm household and nonfarm household. The current versions also provide for estimating income by farm household and nonfarm household. Because of the land reform in the late 1940s and the current 3-hectare limit of ownership of paddy land, there was less concern with the variance of income within the farm sector than between the farm and nonfarm sectors. Thus, for this reason and other reasons discussed later, the distribution of income by levels in the farm sector was not considered in the design of the sector models.

The model does not explicitly take into account aspects of rural development, such as health care systems, educational systems, or transportation and communication systems. The model design, however, allows it to provide input to decisions in these areas with respect to needs and capacity requirements by the agricultural sector and consequences on the sector of infrastructural change.

Agricultural Sector Contribution to National Development. Korean decision-makers are naturally concerned with the contribution of the agricultural sector to total national development in ways that go beyond the production of food to feed the urban population. These contributions include (1) farm household labor for industrial and urban projects (particularly seasonal construction projects); (2) raw materials for industry (e.g., fibers, silk cocoons, medicinal ingredients, etc.); (3) earnings of foreign exchange through export of commodities like silk and import substitution of food and feed grain products; (4) land for nonagricultural uses; (5) savings, government tax revenues, and newly formed capital to develop both farm and nonfarm economies; (6) off-farm migrants who will become permanent residents and contributors of labor in the urban, industrial sector, as well as carrying with them claims on capital in the farm sector. While it is not possible for the sector model to handle endogenously all the flows and levels indicated above; nevertheless, the model should be designed to handle some variables as exogenous inputs (e.g., items 1, 4, and 6) or output others as performance indicators (e.g., items 2, 3, and 5).

Korean Perspective: Improving Administrative Processes

Since the beginning of the MSU project in Korea in 1971, Korean officials have been interested in recommendations from project staff with respect to improving administrative structures within the Ministry of Agriculture and Fisheries. Some of these suggestions which have already been discussed in earlier chapters relate to institutionalizing the human resources and administrative processes to utilize and extend the analytical models. In designing the components of the sector models, the project staff has kept in mind the purposes for which the models might be used. These considerations, in addition to the substantive concerns expressed by decision-makers, have influenced the design of the models.

Perhaps the most important result of this influence is that the models have been designed to be flexible and adaptable. First, this means that the emphasis has not been to build one large comprehensive model which will attempt to answer all foreseeable questions. Rather, the emphasis is on building a set of *modular components*, each of which addresses key questions in various subsectors[2] but which also may be linked together to assess consequences at the sector level for given policy sets. Second, these are *evolving* models that will change with the changing concerns of decision-makers, as well as the ability of succeeding modelers to develop better and continuously current models as assets of the nation's agricultural investigative capacity.

Another implied concern is that the sector model should help to improve the efficiency of the five-year planning process. That is, by harnessing the speed and accuracy of the computer and its ability to process large amounts of data and analyze many complex interrelationships, the process of preparing the five-year plans should be faster, require less manpower, and result in a higher-quality product. In terms of model design, this suggests that the model have a planning horizon of at least five years and that a one-year time increment for processing the model should be sufficient to capture much of the detail required in the five-year planning exercise. This also suggests that the models might be used to develop rolling five-year plans, which are updated once a year with the latest data and latest changes in the development strategy of the decision-makers. The models can also be used to prepare a consistent set of agricultural accounts at the aggregate level. This dimension is useful for intermediate-range outlook reporting.

Another concern is that the model be rich enough in detail to be able to compare and contrast the impact of investment in the various subsectors on total agricultural production and other criteria. This suggests that the model must include the important subsectors: production, consumption, and trade, as well as agricultural-nonagricultural linkages. These are substantive areas, which were mentioned in the previous section. The point, however, is that the model must be helpful in evaluating and comparing alternative programs and projects across the agricultural sector. The tendency in the past is for evaluation and decision about programs and projects to be made in isolation from one another. Thus, the sector model must provide a tool for making these comparisons.

Another implied consideration in model design is that the input policies and the output performance indicators correspond reasonably with the types of policies and indicators familiar to decision-makers. In other words, there must be correspondence between the way the model views the world and the way the decision-makers view the world. As a result, an effort was made to design output tables which were easily understandable and were not too different in format to the types of tables which appeared in agricultural yearbooks and other publications. Definitions of key variables also correspond with previously accepted definitions.

MSU Perspective

In most cases the MSU/USAID perspective was consistent with the Korean perspective with respect to substantive content and administrative style. However, the MSU team had additional concerns which influenced the evolving model design. A primary concern was that the elements of the models, training, and institutional linkages being developed in Korea be useful in other contexts and other countries. Therefore, the objective of the work was not to develop specialized components only useful in the Korean situation. The main influence of this concern was probably at the level of programming and documentation. For example, instead of programming the model to handle exactly 12 crops, it was programmed to handle a number of crops specified by the user. This provides flexibility, not only for using the models in the Korean context, but also if they are applied in other countries.

MSU was also concerned with training students in the systems simulation methodology. Therefore, development components were undertaken as thesis work for Master's or Ph.D. degrees. For example, the crop technology change component of the sector model was developed as a dissertation research topic by a Korean Ph.D. candidate working at Michigan State University. Such an arrangement cannot help but influence the design of the first version of the component and the timing of integration into the total model system.

Sector Model Design

In keeping with the design principles outlined earlier in Chapter 3 on the theory and practice of model building, the Korean Agricultural Sector Model (KASM) is a model comprised of modular components. These components can be either run together to carry out a general sector analysis addressed to many of the questions outlined earlier; or individual components can be decoupled and run to perform specialized analysis related to particular subsectors, such as population, farm production, demand, etc. The basic principle in the design of the model was to allow considerable flexibility in using the model to explore specific policy questions, as well as for general sector analysis and forward planning exercises. An overview of the basic design characteristics of KASM is presented below.

Time

By definition, sector simulation models involve time as a fundamental variable. Design decisions were required with respect to the planning horizon and the incremental time cycle. KASM was designed to operate on a planning horizon of 5 to 15 years, although it has been used for shorter-range analysis in the five-year planning exercises, as well as for longer-range planning up to 25 years. The latter analyses concerned long-term population projections and a study of land and water development priorities. This planning horizon and the general purposes for which the model is to be used influence the choice of the basic time cycle and disaggregation levels included in the model. KASM operates on the basic time cycle of one year (in contrast to the Grain Management Program Model described in Chapter 16, which operates on a time cycle of about two days). This is to say that the levels of endogenous stock variables at the end of one year and the rate variables for the end of the previous year and the rates of change during the past year. In other words, the shortest feedback loop in the model cannot be less than one year. Even though the resource allocation component allocates land and labor for the two main cropping seasons in Korea, nevertheless the seasonal allocations still depend on the levels and rates for the previous year, not the previous season.

Disaggregation Levels

Table 1 summarizes the disaggregation levels for the important dimensions in the model structure.

Population. The population is divided into the farm household population and the nonfarm household population. Each population group is further divided into single-year, age-sex cohorts. It should be noted that the farm household population is not further disaggregated by household income level, which would have been necessary if analysis of the impact of government policies on the distribution of income to the farm population were to be analyzed. This was not done because Korean policy-makers have been much more concerned with the average level of farm household income *vis-à-vis* nonfarm household income. Because there is a three-hectare limit on holdings of paddy land, the distribution of farm income is relatively unskewed compared with other, less-developed countries.[3] To include the agricultural sector income distribution dimension would add considerable complexity to the operating structure of the model, as well as greatly increased problems of parameter estimation. It will likely need to be done, however, at some point in the future if agricultural income distribution becomes a problem.

National vs. Regional Mode. Although the structure of the model was originally designed to operated regionally and included a three-region disaggregation of the country based on crop production patterns, the current version of the model operates at the national sector level. Operating the sector model in the national mode (1) greatly reduces the execution time (approximately 4 minutes for a 15-year run in the national

Table 1. Disaggregation Levels in the Korean Agricultural Sector Model

Population Groups (2)

Farm Household
Nonfarm Household

Agricultural Subsectors (4)

Annual Crop
Perennial Crop
Livestock
Fishery (rudimentary)

Regions (1 or n)

National	"Single-Crop" Region
	"Double-Crop" Region
	"Upland" Region

Agricultural Commodities (19)

1. Rice	6. Pulses	11. Silk (Mulberry)	16. Chicken
2. Barley	7. Vegetables	12. Industrial Crops	17. Eggs
3. Wheat	8. Potatoes	13. Beef	18. Fish
4. Other grains	9. Tobacco	14. Milk	19. Residual
5. Fruits	10. Forage	15. Pork	

Land Categories (4)

Paddy
Summer Upland
Winter Upland (includes double-cropped paddy)
Pasture

Factor Inputs (12)

Land
Labor
Capital (farm implements, tillers, transplanters)
Chemical Fertilizer
Organic Fertilizer
Pesticide
Seed
Fuel
Oil
Other Inputs

mode versus about 35 minutes in the three-region mode); (2) eliminates the extra work of aggregating time series data from the province level to the three ecological regions ("single-crop paddy," "double-crop paddy," "upland") analyzed in the 1972 Korean Agricultural Sector Study; (3) produces output at the national level, the level of first concern for national decision-makers; and (4) allows for testing of the overall design and structure of the sector model (particularly the recursive linear program component, which models resource allocation and production) without introducing the complexity of regionalization. However, because regional questions are important, later versions of the model should provide for "flexible regionalization" and should be linked to data systems which allow flexible aggregation of data inputs to allow analysis at levels of aggregation specified by the researcher.

Agricultural Commodities. The many different agricultural commodities which Korea produces[4] have been aggregated into the following 19 product groups: rice, barley, wheat, other grains, fruits, pulses, vegetables, potatoes, tobacco, forage, silk (mulberry), industrial crops, beef, milk, pork, chicken, eggs, fish, and a residual category.

Factor Inputs. The following factor inputs are accounted for: land, labor, capital, chemical fertilizer, pesticides, seeds, fuel, oil, and other inputs. Four land categories are considered: paddy, summer upland, winter upland (including double-cropped paddy), and pasture. Capital inputs are further disaggregated into farm implements, tillers, and transplanters. Chemical fertilizer is not yet disaggregated into the three basic nutrients; disaggregation may be done in later versions.

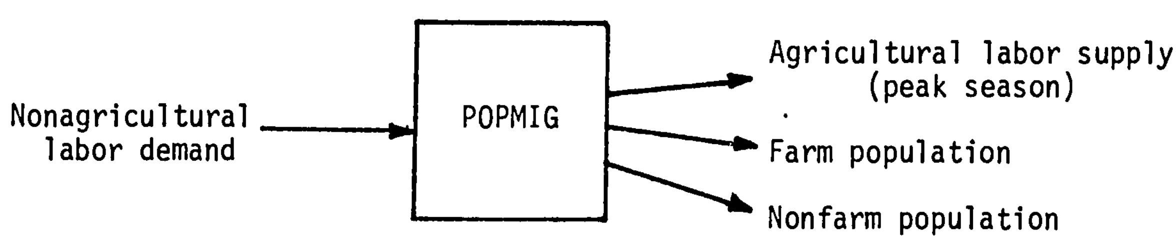
Components and Linkages

The structure of the model is organized into five main analytical components: (1) population, (2) national economy, (3) yield and input, (4) farm resource allocation and production, and (5) demand/price/trade plus an accounting component. The resource allocation and production components include subcomponents for annual crops, perennial crops, and livestock production.

The components can be linked together to carry out a full-scale sector analysis or run separately and in combination for subsector analyses. Figure 2 is a diagram indicating the linkages between components for a full-scale sector analysis.

Population and Migration Component (POPMIG). The population and migration component simulates farm and nonfarm population dynamics, including the process of off-farm migration. The effects of government birth control and public health policies may be indirectly input to the model by means of exogenous projections of fertility and mortality. POP outputs farm and nonfarm population levels, which are the main driving forces behind food demand, and agricultural labor supply, which influences rates of farm mechanization.

The main linkages of POPMIG with the other KASM components are,



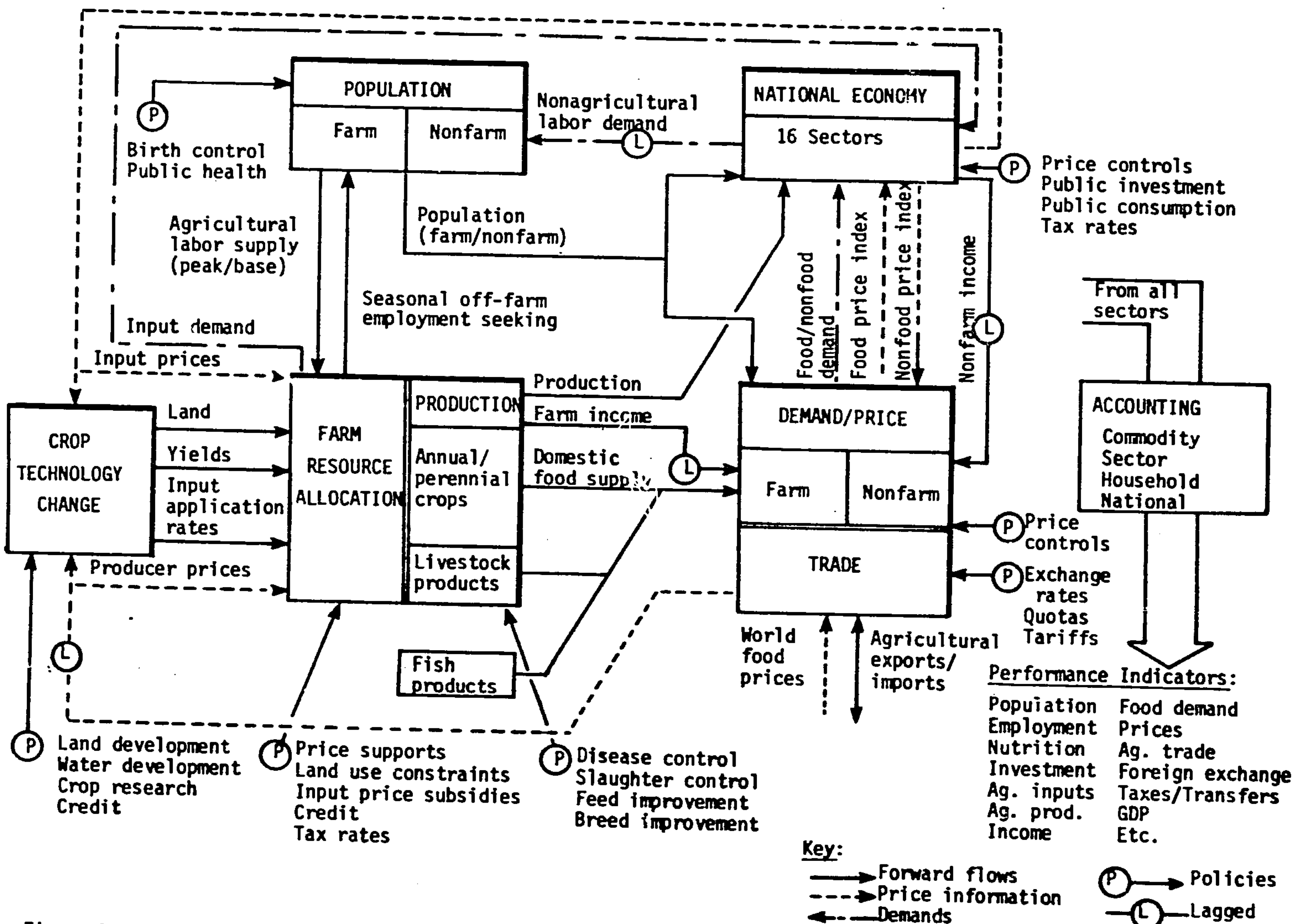
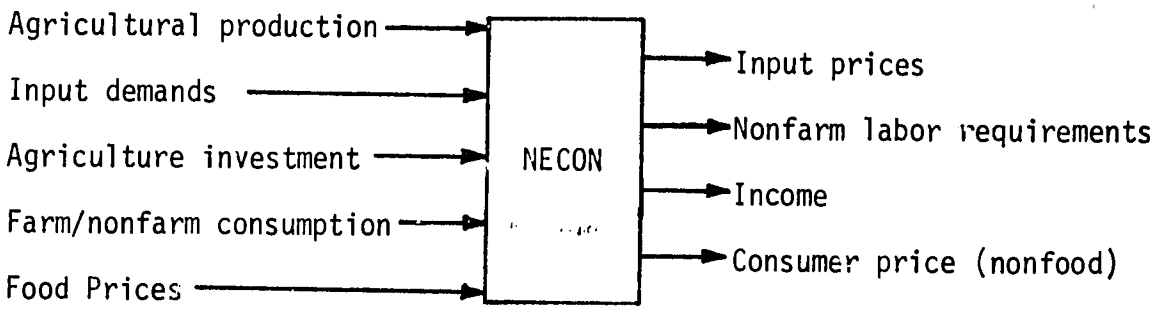


Figure 2. Korean Agricultural Sector Model: System Linkage Diagram

National Economy Component (NECON). The national economy component uses a 16-sector input-output model to simulate the important feedback linkages affecting the growth of the agricultural and nonagricultural sectors. For example, government programs to increase agricultural production can stimulate the demand for nonagricultural production by increasing the purchasing power of farm households. Increased nonagricultural production in turn increases nonfarm income and, hence, food demand, thus stimulating further growth in the agricultural sector. NECON's strongest ties are with DEMAND. Farm and nonfarm incomes, exponentially averaged, affect the income response in the consumption functions in DEMAND. Also, the aggregate price index helps determine expenditures on nonfood goods and services. Agricultural input price indices are inputs to the production components (CHANGE and FRESAL). Intermediate input demands and agricultural output from FRESAL are used to modify the agricultural coefficients in NECON's input-output technology matrix. In addition, the demands from agriculture for investment goods are part of the final demand to the sectors in NECON which produce capital goods. NECON uses projections of farm and nonfarm populations in its consumption subcomponent and to compute per capita values of accounting variables. NECON's projections of labor requirements in the nonagricultural sectors are used by POPMIG as a driving force for off-farm migration.

Since KASM is primarily concerned with agricultural sector analyses, the allowable policy inputs to NECON involve only nonstructural changes in the nonagricultural sectors. These policy inputs include projections of foreign exchange rates and farm and nonfarm income tax rates. Also, policy inputs for each of the 15 nonagricultural sectors include indirect tax rates, import tariffs, targets for import substitution levels, projections of public investment, and public consumption. Exogenous projections of the dollar export volumes and world prices for each sector over time are also required by NECON.

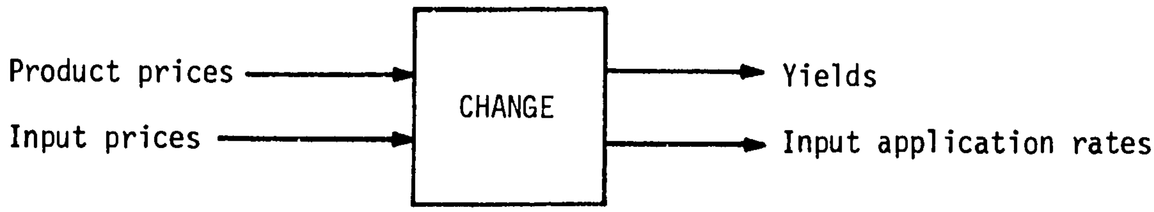
The main linkages of NECON with other KASM components are,



Crop Technology Change Component (CHANGE). The crop technology change component models the processes whereby the agricultural land/water resource base, variable input utilization, and, hence, productivities or yield levels of crops, change over time. The processes involve changes in the technology, institutions, and human resources associated with the agricultural resource base, particularly as generated through public policies, programs, and projects. CHANGE links public investment decisions with private decisions at the aggregated farm-firm level. The public policies which can be input into CHANGE concern (1) investments in land and water development programs (multipurpose irrigation, consolidation, drainage, reclamation, conservation, pasture improvement); (2) investment in crop improvement research; (3) price policies (for inputs and products); and (4) credit policies.

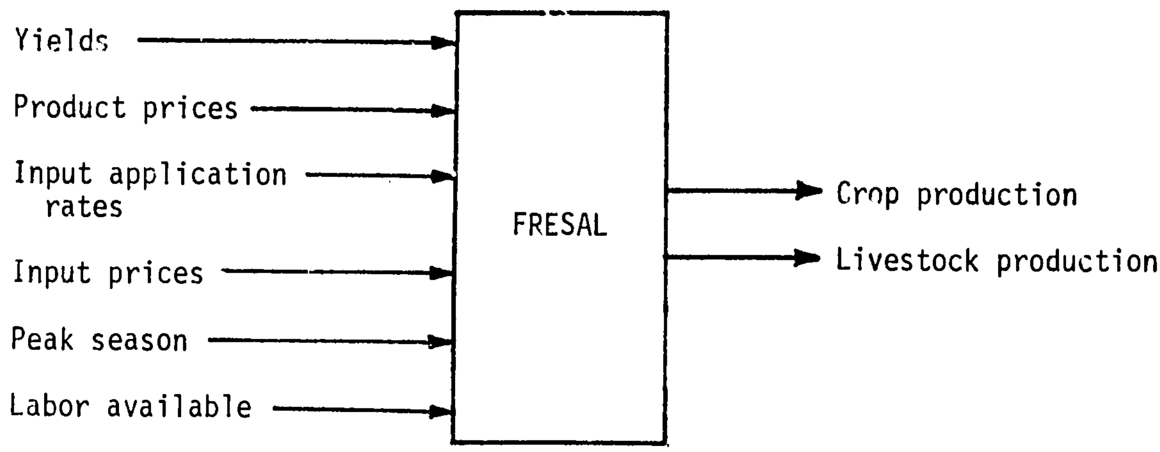
Crop yields, input utilization rates (fertilizer, chemicals, other materials, and labor), and total land by type (paddy, upland, potential double-crop land, and pasture land) are fed as inputs to the resource allocation and production component (FRESAL).

The main linkages of CHANGE with other KASM components are,



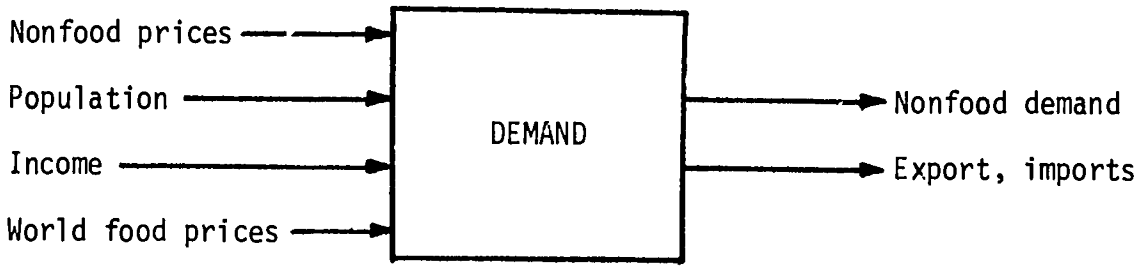
Farm Resource Allocation and Production Component (FRESAL). The resource allocation and production component uses a recursive linear programming model to simulate the annual resource allocation and production activities of the aggregated farm households as behavioral decision units. In addition to the inputs from CHANGE, other inputs include peak-season and base farm labor supply (from POPMIG), lagged producer prices (from DEMAND), and lagged input prices (from NECON). Policy inputs include commodity price supports, input price subsidies, credit constraints, interest rates, tax rates, and land use constraints. FRESAL outputs the domestic supply of 12 crop commodities (rice, barley, wheat, other grains, fruits, pulses, vegetables, potatoes, tobacco, forage, raw silk, and industrial crops) and five livestock commodities (beef, milk, pork, chicken, and eggs). The production of fish and the production of residual food are determined exogenously. Other outputs include agricultural farm income, feed grain imports, input demand, technology levels, shadow price of fixed resources, capital stock, savings, and indebtedness.

The main linkages of FRESAL with other KASM components are,



Demand/Price/Trade Component (DEMAND). The demand/price/trade component projects farm and nonfarm food consumption, producer and consumer prices, agricultural trade, and per capita nutritional levels, based on effective demand. Domestic food supply, population, and lagged income are the major inputs into DEMAND from other components. A number of policy options have been built into DEMAND in order to handle the many, sometimes conflicting, objectives of price and consumption policies. For example, increased domestic production and high producer income may be the objective of higher producer prices. Also, reduced food imports and foreign exchange costs may be the objective of import controls, higher consumer prices, and administrative measures. Finally, reducing inflation, controlling industrial wage costs, and maintaining the competitive position of export industries may be the goals of consumer price controls. In DEMAND each commodity must have one and only one policy from the "mutually exclusive" set and may have either policy (or both) from the "independent" set. These policy options are commodity specific, so that the policy for rice may differ from that for barley. A "default" policy set controls the model in the absence of a specific alternative policy.

The main linkages of DEMAND with other KASM components are,



Accounting Component. The accounting component is a set of print and plot subroutines which produce the tables and graphs summarizing the behavior of the various performance indicators over the planning horizon being considered. The output from a simulation run may be presented as a series of annual summary tables and/or summary time series plots.

Policy Analysis with the Sector Model

The Korean Agricultural Sector Model (KASM) is flexible enough in its present formulation to address a number of different policy questions.

Single-Run Analyses

The simplest mode of operation is to project for a 5-, 10-, or 25-year period the values of performance indicators of interest to decision-makers under a set of policy assumptions which may have been determined independently of the model--either through the bureaucratic process of the political process. The value of the model in this case is that it can quickly produce a consistent set of results. For example, for the five-year plan projections the model might project the supply, demand, prices, imports, and export of the main agricultural commodities; the agricultural input requirements; farm household income and off-farm migration rates; and other, more detailed economic, demographic, and nutrition indicators. The model can also be used to update these projections as new data become available. The model can also be used to explore the consequences of sudden "shocks" to the Korean economy, resulting, for example, from sharp increases in world grain prices for a several-year period or a sudden collapse in the world price of raw silk or sharp increases in fuel prices.

In both of these modes of utilization the focus of the decision-maker is on the results from a single run. In the latter case, for example, the decision-maker might be asking, Can I really accept that large a deficit in the Grain Management Special Account under such a sharp increase in world price, given my current grain price policies, or must I change my policies?

Comparative Policy Analysis

Most system investigators feel more comfortable in using the models for comparative policy analyses rather than in a single-run analysis. The reason is that they consider the models good enough to capture the major trends and operating characteristics of the system but recognize that under uncertainty conditions the models cannot predict exactly what the actual values of the performance indicators will be 5, 10, and 25 years into the future.

The usual mode of operation for this type of analysis is to specify a "base" run of the model in which currentpolicies are assumed to continue into the future and/or no additional investment activity is specified (e.g., no further investment in land and water development). Then several different alternatives, short-term policies or longer-term strategies of development, are run and their results compared with the results of the base run along a number of different dimensions of interest to the decision-maker.

The following are examples of comparative policy analysis which may be carried out using the current version of KASM.

Price Policy Analysis. Price policies are usually considered to be short-term control measures. Producer and consumer price policies usually have conflicting objectives. Increased domestic production and high producer income may be the objective of higher producer prices. Reduced food imports and foreign exchange costs may be the objective of import controls, higher consumer prices, and administrative measures. Reduced inflation, controlling industrial wage costs, and maintaining the competitive position of export industries may be the goal of consumer price controls. In order to consider these policy questions, a number of price and import policy options have been built into KASM.

Tax and Credit Policies. The government can control directly the tax rates levied on agricultural production and income and, also, indirectly, credit available to the agricultural sector by guaranteeing certain types of loans. KASM allows the policy-planner to compose alternative tax rates and credit policies, particularly to explore impact on agricultural production and farm income.

<u>Public Investment Policy Analysis</u>. This type of analysis is usually carried out for a long-term investment pr gram. One might analyze alternative public investments in biological research, extension, and land and water development on agricultural production and the demand for factor inputs (fertilizer, machinery, etc.) from the nonagricultural sector. Or, alternatively, one might analyze the impact of supply constraints and/or prices of factor inputs on agricultural production resulting from policies in the nonagricultural sector.

A later chapter (Chapter 15) is a detailed case study of the use of KASM coupled with a polyperiod linear programming model to analyze land and water development strategies, which include projects in migration, drainage, land consolidation, and reclamation of tidal land and forested slopeland.

<u>Population Policies</u>. The policy-planner can use KASM to explore the effect of different assumptions regarding the rate of decline of fertility rates on future population and the future labor supply. There are insufficient theories and data available to directly link expenditures on the family planning program with changes in the fertility rates.

Through the migration mechanism, the planner can explore the effects of changes in the rate of off-farm migration on the future supply of agricultural labor and, thus, the impetus to increased farm mechanization. This may be done by either adjusting the off-farm migration rate exogenously or indirectly by adjusting employment generation policies in the nonagricultural sector. There is also provision for testing policies which encourage emigration, although it is doubtful whether these policies would have much effect, unless done on a fairly large scale.

The following chapters describe the five major components of KASM in greater detail. As part of the discussion of each component, the types of problems which can be addressed from the problem set within the domain of the agricultural sector are indicated.

FOOTNOTES

[1]Currently referred to in the literature as "rural development" or "integrated rural development."

[2]Useable at the bureau level within MAF.

[3]Gini ratios of .255 and .270 have been calculated for income distribution in the Korean agricultural sector for 1965 and 1974, respectively. Thus, Korean agricultural sector income appears quite equally distributed and is not growing appreciably more unequal over time.

[4]The Yearbook of Agriculture and Forestry includes production statistics on more than 100 different crops and livestock numbers for 15 different species.

REFERENCE

[1] Rossmiller, George E., *et al.* Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985. Seoul: National Agricultural Economics Research Institute, 1972.

CHAPTER 8

THE POPULATION COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

Tom W. Carroll
John E. Sloboda

The purpose of the population and migration component (POPMIG) is to project the changes in the number and structure of the population over a planning horizon of 5 to 25 years. In order to explore structural changes of interest to agricultural development, the total population is divided into the farm household population and nonfarm household population, with each population sector group being further divided into single-year, age-sex cohorts. A standard cohort survival model is used to age and regenerate the two population groups. Off-farm migration is either specified exogenously or determined endogenously as a function of the gap between the demand for nonagricultural labor and the labor supplied by the internal growth of the nonfarm population. The main outputs from the population component are population numbers and labor supply. Nutritional needs in terms of daily protein and calorie requirements are also calculated.

The main inputs which can be indirectly influenced by policy decisions are age-specific fertility rates, age-sex-specific mortality rates, age-sex-specific off farm migration rates, or alternatively, nonagricultural labor demand from farm and nonfarm households.

Figure 1 is a diagram showing the linkage between the population component and other components in KASM. The population component may also be run as an independent model, provided the necessary exogenous projections are specified.

Component Structure

In addition to initialization of the base-year population, the population component carries out six basic operations during its annual update cycle in the following sequence:

Aging of the population

Determination of single-age military service rates

Internal migration

Emigration

Fertility and infant mortality

Calculation of updated demographic, economic, and nutritional variables

Initialization

The model accepts estimates of the national and farm household populations by five-year, age-sex groups for the ages 0-4 through 80-84, and for the 85+ group for the different starting base years. These base years are usually selected to correspond to census years, when the best estimates of the population levels are available.

The purpose of the initialization operation is to derive single-year, age-sex cohorts for the farm household and nonfarm household populations from the five-year, age-sex cohorts for the national and farm household populations which have been inputed into the model.

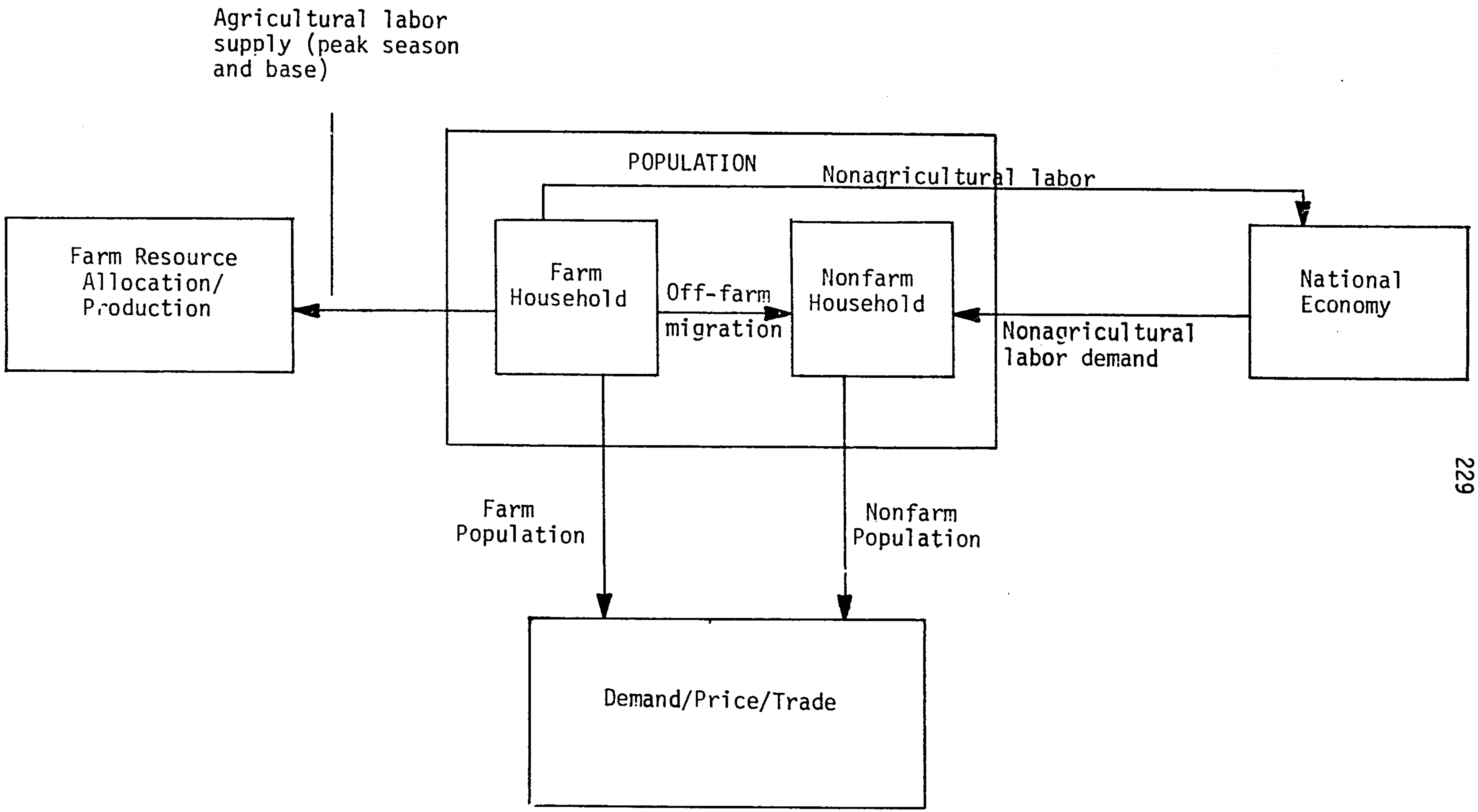


Figure 1. Linkages between POPMIG and Other Components of KASM

The initialization is done in three steps. Since the normal census practice is to include all military service personnel in the nonfarm population, the first step involves redistributing military service personnel from the nonfarm population across both the farm and nonfarm populations. This is done because experience in estimating the off-farm migration rates (particularly in Korea, which has a large military force relative to population size) indicates that it is better not to confound off-farm migration with induction into military service. It is assumed, therefore, that the decision of whether to leave the farm sector is made after completing military service. After adjusting the farm household population to include members in the military, the farm household population is subtracted from the total national population in order to obtain the nonfarm population by five-year, age-sex groups. In the final step, the five-year, age-sex cohorts for the farm and nonfarm populations are distributed into single-year, age-sex groups for the ages 0-84 using the Sprague method. The Sprague distribution function employs for each five-year cohort a set of coefficients by which a set of five-year cohorts are multiplied in order to separate each five-year cohort into single-year cohorts. The coefficients were determined by Thomas B. Sprague from a fifth-difference osculatory interpolation formula. The Sprague method and other curve-fitting techniques may be found in [11]. The terminal group, age 85 years and over, is retained in aggregate form.

Aging and Mortality

The aging of each population stream is the first operation carried out in the annual population update phase of the model. The standard cohort survival mechanism is used whereby each single-year cohort from age 0 to age 83 is multiplied by an appropriate single-year survival ratio. The terminal-year age group is determined by multiplying the population 84 and over at the beginning of the cycle by an estimate of the proportion which will survive to reach age 85 and over one year later.

Determination of Military Service Rates

The purpose of this step is to adjust the age-specific military service rate profile. Because of the size of the military forces in a country like Korea,[1] it is important that the effect of military service on patterns of migration and labor force participation be explicitly considered. Due to military service, a large proportion of the males from farm households in the ages 20-24 are recorded in the nonfarm household population at any given time. This has a very important impact on patterns of off-farm migration calculated directly from census data by raising the apparent rate sharply in the age group 20-24 and lowering it, sometimes to negative values, in the age group 25-29, when many conscriptees are returning. Moreover, since the conscriptees are outside the civilian labor force, the size and age structure of the armed forces population also has an impact on the operation of the migration mechanism, which depends on the growth of nonagricultural employment.

Since the use of constant age-specific military service rates for all years of a simulation run would lead to unreasonable estimates of the size of military forces for some periods, the current approach is to exogenously specify the number of full-time, noncareer military personnel over the time period of a simulation run. Then, the age-specific military service rate profile is raised or lowered by a uniform multiplier to generate new age-specific rates for the ages 19 through 35, which, when multiplied by and summed across the male age distribution, will yield the exogenously specified number of military personnel.

Migration

The off-farm migration mechanism operates in two modes. The first mode may be characterized as a "policy parameter approach." In this mode the net overall rate of off-farm migration is specified exogenously over the time period of a simulation run. The second mode may be characterized as a "labor supply-demand approach." In this approach the net overall rate of off-farm migration is determined endogenously in order to satisfy a nonagricultural labor demand-supply gap in the nonfarm sector.

The off-farm migration mechanism is an iterative, three-step operation involving both a net overall rate of off-farm migration and an age-specific net migration rate profile. In the first step the "current" net migration rate profile is applied to the population at risk to determine an *ex ante* estimate of net migration between the two sectors.

In the second step the ratio between the *ex ante* estimate of a criterion variable (depending on the mode) and the criterion variable is calculated. In the "policy parameter mode" the criterion variable is the exogenously specified net overall rate of off-farm migration. In the "labor supply-demand mode" the criterion variable is the number of employed migrants, which is equivalent to the excess of demand for nonagricultural labor in the nonfarm sector over the *ex ante* supply. The excess of demand over supply is calculated as a function of (a) total nonagricultural labor demand (either exogenously specified or provided by the national economy component), (b) net off-farm labor supplied directly from the farm household population to the nonfarm sector, (c) an exogenously specified urban unemployment rate, (d) age-sex-specific economic activity levels among the nonfarm civilian population, and (e) the civilian population distribution.

In the final step the ratio calculated above is used as a constant multiplier to adjust the nominal off-farm migration rate profile up or down. To obtain age-sex-specific number of migrants, the farm population distribution is multiplied by the adjusted migration rate profile.[2]

Having discussed the basic migration mechanisms, let us now turn to some of the assumptions embedded in the model regarding migration. The net migration profile referred to above is used to provide a pattern of relationships between the propensities to migrate among different age-sex cohorts. The operative assumption of the model is that while age-sex-specific net migration may vary over time, the relationships between the rates for any two age-sex groups remains constant. The relative differences between the net migration rates for the different age-sex groups reflected in the net migration profile are thought of as being determined both by individual and societal factors which influence intersectoral occupational mobility and the relationship between rates at different ages which arise through migration in family units.

The net migration approach could not be considered an appropriate dependent variable in analytical models which take a behavioral approach to interregional or interoccupational migration, since the number of "net migrants" and the net migration rate are simply artifacts of the cross-currents of real population movements. Nevertheless, it has been necessary to use a net migration approach in the current population model because of the lack of information on gross movements between the farm and nonfarm sectors. Although gross rural-urban migration statistics are available in Korea, research by Sloboda indicates distinct differences between these patterns and that of farm-nonfarm movement. Finally, it should be noted that the conceptual and theoretical difficulties involved in using net migration rates are less severe in the case of farm-nonfarm movement than in the case of rural-urban movement because of the relatively greater "efficiency" of the former, particularly in the younger age cohorts, which comprise the bulk of the migration stream.[3]

It should be noted that in the "labor supply-demand approach," migration is a direct function of the nonagricultural labor demand and the unemployment rate. The former may be either exogenously specified or provided by the national economy component. The unemployment rate must be exogenously specified in the current model.

Emigration

Between 1955 and 1970 net annual emigration from Korea was insignificant, but in recent years the number of emigrants has increased sharply and the government has announced that it will promote overseas emigration by farmers and semiskilled workers while seeking to limit the outflow of skilled persons and capital. It remains to be seen to what extent persons with limited skills and resources will seek to emigrate and whether the potential recipient countries will be willing to accept such immigrants. Certainly past experience in Korea and elsewhere strongly suggests that voluntary emigrants will tend to be positively selected in terms of those human and financial resources which facilitate successful adaptation to a new social environment. Moreover, immigration policies are being reconsidered in the United States, Canada, and the countries of Latin America which are expected to absorb most Korean emigrants; and it is expected that these countries will become more selective and restrictive in the future.

Based on these considerations, we have assumed that all emigrants will be drawn from the nonfarm household population. No consistent data on past emigration trends could be obtained, and no records are apparently kept of the number of persons who successfully obtain immigrant status after going overseas for study or on business. Because no information was available on the age distribution of approved emigrants, let alone for *net* emigrants, it was simply assumed that one-half of the net emigrants will be between the ages of 20 and 39, while one-fourth will be age 1-19, and the remaining one-fourth between the ages of 40 and 59. Within each of these broad age groupings, net emigrants are assumed to be distributed in proportion to the size of each single-year age-sex cohort.

Fertility and Infant Mortality

The determination of births, infant deaths, and the resulting population of age 0 in each sector at the end of the year is made subsequent to all adjustments for mortality, migration, and emigration. Separate patterns of age-specific fertility, varying over time, are assumed for the farm and nonfarm populations. Alternative assumptions concerning the changing pattern of fertility can be incorporated (albeit somewhat crudely) *vis à vis* a sectoral fertility adjustment coefficient within the model. Infant survival rates for the period from birth to the end of the update cycle are assumed to be the same in both sectors but vary over time. The algorithm for calculating live births takes into account that the appropriate population at risk in bearing children is the number of women who survive to the end of the year plus half of those who are estimated to have died during the year. The same ratio of male to female births is assumed for both farm and nonfarm women.

Calculation of Updated Demographic, Labor Force, and Nutritional Variables

Demographic Variables. The preceding operational steps in the annual update cycle yield an updated population distribution by sex and single-year age cohorts for each sector. These two population distributions include the active military service personnel in the sector of permanent residence and are used to calculate the crude birth rate, crude death rate, and crude growth rate for each sector and for the nation as a whole. An *ex post* net off-farm migration rate is also calculated. Next, new population distributions for the populations actually in residence for each sector are created by transferring farm household military personnel to the nonfarm sector. The *de facto* residential population distributions provide a basis for comparing the projected population in each sector with actual census data. These populations are also used to calculate agricultural labor force and to determine nutritional requirements by sector.

Labor force variables. The principal labor force variables calculated are the nonfarm labor force, nonfarm employment and unemployment, the base agricultural labor force, and the potential peak-season agricultural labor force. The nonfarm labor force and nonfarm employment are calculated on the basis of nonfarm and migrant economic activity rates, projected total nonagricultural employment, estimated farm household nonagricultural employment, and estimated nonfarm unemployment rates.

The base agricultural labor force is determined in the model by applying estimated age-sex-specific rates of the base agricultural labor force participation to the in-residence farm household population distribution. Age-sex-specific data were available on the proportion of a cohort reporting itself as working "mainly in agriculture" and the proportion reporting more than 90 days of work in agriculture. The larger of these two proportions was taken as the base agricultural labor force participation rate for the five-year, age-sex group.

Recent years have witnessed reports of agricultural labor shortages during the two peak seasons which typically occur during June and October, spanning a total of roughly 60 days in any one area. Under the assumption that only the farm household population currently in residence can provide labor to the agricultural sector, the model estimates

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nonfarm household populations. These nutritional requirements provide a standard against which the effective demand calculated in the demand component as a function of prices and income may be compared. Average daily age-sex-specific calorie and protein requirements per kilogram of body weight are applied to projected changes in body weight to give these estimates of nutritional requirements. Additional calorie and protein requirements are also included to account for the additional needs associated wtih pregnancy and nursing. Both requirements are specified for the population of age 0, with the allowance for pregnancy covering the full 280 days of pregnancy and for nursing covering 10 months, a period chosen to represent average nursing practice. The nursing allowance is adjusted to provide for an 80-per-cent efficiency factor in converting calories to milk.

For the adult population (age 20 and over) the calorie requirement is based on the level of work activity. This results in the farm population having a higher calorie requirement. The base of the model is the 1970 level of work activity. A change in the level of work activity may be incorporated by means of changing the calorie requirement per kilogram of body weight. A parallel adjustment is also included to provide for changes in average body weights of each age-sex-cohort over time. In both cases, the model employs an estimate for 1970 and a projection for the year 2000 and then linearly interpolates for the intervening years.

Data Requirements

The data requirements for each of the operational steps are reviewed below.

Initialization

Estimates of the national and farm household populations by five-year, age-sex groups for the ages 0-4 through 80-84 and 85+, with foreigners excluded, have been prepared for three different base years: 1960, 1966, and 1970. Both the national and farm populations for 1960 and 1966 are based respectively on the 1960 and 1966 Population Censuses, with some upward adjustment for underenumeration. The national population for 1970 is based on the most recent revised Economic Planning Board adjustments to the 1970 Population Census; the farm population for 1970 is based on the 1970 Agricultural Census, with adjustments for underenumeration. Sources of data for initializing populations in 1960, 1966, and 1970 include [3, 4, 5, 8].

Mortality

The single-year survival ratios used in the aging operation are based on estimated single-year 1_a values interpolated from the Coale-Demeny model life tables. Different levels of the West family of Coale-Demeny model life tables were selected to represent the mortality regimes expected to hold for Korea at different times between 1960 and 2000. The selection of the Coale-Demeny levels was based on estimates of past and future Korean life expectancy taken from several sources, and the schedule of levels employed in the model reflects roughly the mean values of these estimates. To obtain the 1_a values for these fractional Coale-Demeny levels, single-year 1_a values were first estimated outside the model for the ages 0, 1, 2, 3, 4, 5, 10, 15, ..., 65, 70, 75, 78, 80, 82, 83 for West levels 15 through 23 by linear interpolation. These derived l_a values were also used to extrapolate l_a values through age 100 at each benchmark level, providing the basis for calculating survival ratios for the terminal age group. Single-year survival ratios for ages other than those specified and for West levels other than the integer levels 15 through 23 are determined within the model through two-way linear interpolation.

While the model allows for possible differences between farm and nonfarm mortality levels, no specific data are available on urban-rural mortality differences in Korea. However, there is no reason to believe that the differences are substantial, and it is likely that the differences between farm and nonfarm households would be even narrower.

Military Service Rates

Although there are no available official statistics on the size and age distribution of ROK military personnel, these can be estimated indirectly with reasonable accuracy from census data. A comparison between the male five-year cohort populations indicated in Vol. 4-1 of the 1970 Census of Population and Housing [6] and the population in each cohort for which economic activity status is indicated reveals a discrepancy of 599,000 men between the ages of 15 and 54 for whom no economic activity status is reported. This number and the age distribution is very close to that which one might expect for the population in active military service. These data formed the basis for calculating a nominal age-specific, national average military service rate profile, as required by the population component.

Migration

Since no statistics directly measuring off-farm migration are available for Korea and because of indications that the pattern of off-farm migration has differed significantly from the pattern of net rural-urban migration, off-farm migration was estimated from aggregate population data using the census-survival ratio approach (forward projection method). To produce an unbiased estimate of the net migration rate, this method requires that the population be closed to external migration, that interregional or intersectoral differences in age-specific mortality rates be negligible, and that the ratio of the regional (or sectoral) enumeration ratio to the national enumeration ratio be the same in both censuses for each age-sex group and the same for every age-sex group in the region or sector [7]. The first condition was approximately satisfied for Korea during the period 1960-1970; and if the KASM/POPMIG adjusted census population were employed, it is believed that the remaining conditions would be sufficiently closely approximated to justify using this approach. Under the CSR method, as employed here, net off-farm migration and the net off-farm migration rate for each five-year, age-sex group is calculated by estimating the survival ratio from time 1 to time 2 from the national population totals, multiplying this survival ratio times the farm population in the appropriate ages at time 1 to determine the expected farm population age a at time 2 in the absence of net migration, and subtracting this expected population from the actual farm population in the same birth cohorts at time 2 to estimate the extent of net migration. This estimate is a measure of migration among those who survive to the end of the period, and the net migration rate is thus appropriately calculated on the basis of the average farm population during the period, counting only those who survive to the end of the period (i.e., the average population at risk).

In order to avoid sharp fluctuations in the net migration rate profile for males between the ages of 20 and 30 caused by entering and leaving military service, the census-survival ratio approach was applied to the populations adjusted to include military personnel in the sector of origin. Because the age-sex selectivity of the military-adjusted net off-farm migration rates during 1966-70 were believed to be too sharply peaked among young adults to be representative of migration patterns holding over the next several decades, it was decided to use the 1960-70 net migration rates as the profile pattern in the model.

Both the migration mechanism and the labor force calculations require estimates of the age-sex, economically active population rates and the urban nonfarm unemployment rate. Sources for these data in Korea included [2, 8].

Emigration

In the absence of more appropriate information, the assumptions concerning emigration currently employed in the model are based on data provided by the Ministry of Health and Social Affairs on the annual number of approved petitions for emigration between 1960 and 1973. These are gross figures, but the number of returning emigrants is probably more than offset by the degree to which these shortfall actual emigration. Assumptions about the projections of the historical data into the future must be input into the model.

Fertility and Infant Mortality

The basis for estimating and projecting age-specific fertility in Korea was the L. J. Cho estimates of age-specific fertility among the urban and rural populations during the period 1959-70 [1] and the average of the two estimates of the 1973 national age-specific fertility rates, based on the Continuous Demographic Survey and the 1974 Korean National Fertility Survey. The Cho estimates are based on census data, using the "own-children" method devised by Cho and Grabill. Next, a least-square regression of the general form

$$R_t(a) = A_a * e^{B_a t}$$

was fit to the age-specific fertility data for each age group and each sector. The estimation parameters, A_a and B_a were then used to derive benchmark age-specific fertility rates for each sector at five-year intervals between 1960 and 1995. This approach to projecting fertility trends paralleled that used by the Korean Development Institute to prepare national population projections for the Fourth Five-Year Economic Development Plan.

The exogenous projection of fertility outside the model and independent of other variables is theoretically unsatisfying, especially since fertility is the major variable in determining the future growth of the Korean population. However, the theoretical and empirical basis for estimating fertility as a function of other variables is relatively weak, and efforts in this area carried out elsewhere suggest that the estimates that would be yielded by any of the current generation of causal fertility models are likely to be further off the mark than a well-considered exogenous projection. The KDI "trend" projections of national fertility were deemed a reasonable basis for a "target" population projection for population policy during the Fourth Five-Year Plan because they remained fairly close to the fertility patterns experienced in Japan in terms of the relationship of age-specific fertility rates at each given level of total fertility. The KDI projections suggested a slower rate of fertility decline than that which occurred in Japan: according to the KDI projections, total fertility is forecast to decline from 3.85 in 1973 to around 2.1 in 1993--roughly paralleling the drop which occurred in Japan between 1950 and 1958. A slower rate of overall decline in Korea was deemed realistic in light of differences in historical patterns of fertility, differences in the educational attainment levels of fertile women at the beginning of the period of rapid decline, differences in levels of female labor force participation, and differences in the proportion of fertile females in farm households.

Since age-specific fertility rates could only be estimated by five-year age groups, given the available data, single-year fertility rates were derived by entering the five-year, age-sex fertility rates as single-year values at the average exact age of the cohort and interpolating other single-age fertility rates through the table function routines used in the model.

The same ratio of male to female births is assumed for both farm and nonfarm women. The sex ratio assumed in the model is 105.5 male births per 100 female births, somewhat higher than the average in countries with complete birth records, but consistent with Korean demographic patterns. Infant survival ratios were computed from the same

Coale-Demeny model life tables used to estimate survival ratios at other ages and are handled in exactly the same manner in the model.

Labor Supply

In the farm household sector the model requires age-sex-specific proportions of the farm household population who participate in the base agricultural labor force (i.e., either work more than 90 days in agriculture or are working mainly in agriculture) and the peak-season labor force. These estimates were derived from [8]. To estimate the rate of participation in the peak-season labor force, it was assumed that those who worked less than full time in agriculture were drawn into the labor force when demand was greatest. Data were available on the number working in agriculture 0-30 days, 30-60 days, 60-90 days, and more than 90 days. Thus, it was assumed that those working fewer than thirty days in agriculture in 1970 worked an average of 15 days and that all of these labor days were contributed during the peak season. Those working 30-60 days were assumed to have contributed an average of 45 labor days, all during the peak season. And those working 60 or more days were assumed to have contributed an average of 45 labor days, all during the peak season. And those working 60 or more days were assumed to have been available for the entirety of the peak season. Thus, a weighted, age-sex-specific, peak-season, labor-force participation rate was calculated.

Although it may be unrealistic to assume that those working fewer than 60 days in agriculture work only during the peak periods, the error introduced by this assumption is probably offset by the likelihood that as effective peak-season labor demand increases, the amount of labor contributed by nonfull-time agricultural workers will also rise. This is already occurring, as is evident from the fact that the fraction of farm women of all ages and farm men over 60 who worked more than 60 days in agriculture was higher in the 1970 Agricultural Census than in the agricultural census of a decade earlier. Both the base and peak agricultural labor force estimates are translated into adult male equivalents, using coefficients which reduce the human power output of young laborers under age 20, women between ages 20-55, and older laborers over age 55, relative to a reference male age 20-55 [9].

In the nonfarm household sector, the model makes estimates of the employed nonfarm population using age-sex-specific economic activity rates combined with the overall nonfarm unemployment rate. The source for these data has been [2]. Unpublished data from the 1970 census indicate that civilian migrant economic activity rates differ significantly from those of the nonmigrant population; provision for this differential is built into the model.

The assumptions concerning the growth of total nonagricultural employment are based on preliminary projections made for the Fourth Five-Year Plan (1977-81) by economists at the Korean Development Institute.

Projections of nonagricultural employment in farm households may be provided to the model in two modes: (1) a projection of the absolute amount of employment, with the current projections being directly extrapolated from data for 1960 to 1970, assuming the historical 4.5-per-cent annual growth would continue; or (2) an exogenously projected number of off-farm workers per farm household, where the number of farm households is calculated as a proportion of the number of farm males, ages 25-59.

Nutrition

In order to calculate nutritional requirements, the model requires estimates of average daily age-sex-specific calorie (KCal) and protein requirements per kilogram of body weight and projected changes in age-sex-specific body weights.[4]

Policy Inputs

Of the various data input requirements summarized above, none, with the possible exception of the size of the military forces, is a policy instrument directly controllable by governmental decision-makers. Some data inputs are clearly influenceable by governmental policies and programs. For example, the rate of decline in fertility rates should be influenceable by effort expended on the family planning programs, while mortality rates should be affected by expenditures on public health programs. Emigration rates would be influenced by government targets and subsidies.

Testing

The structure of the population component is not particularly complex nor sophisticated. It is essentially an "accounting model" which keeps track of people by their attributional characteristics (age, sex, sector, employment, etc.). Thus, from a structural, operational point of view, not much work was required to test the logical consistency of the model structure. The main effort has gone into using the model to check the consistency of the data inputs which have been derived from a variety of sources and making judicial adjustments where it seems appropriate. For example, calibration runs, with the model using the initial arrays of farm and nonfarm age-specific fertility, gave evidence that in general, actual farm household fertility exceeded Cho's estimates for the rural sector as a whole, while nonfarm fertility was somewhat lower than that estimated for the urban sector. This discrepancy evidenced itself in sharp discontinuities between the size of the population aged 0 in 1961, 1967, and 1971, compared to the population aged 1 in the same years, as projected within the model from the KASM/POPMIG base populations. This gap was closed by adjusting the fertility adjustment coefficient (FRTAJ) to raise or lower total fertility (and age-specific fertility) by the required amount.

Current testing indicates that the projection of off-farm migration rates and, hence, the farm/nonfarm split, and available agricultural labor supply are very sensitive, as might be expected, to assumptions about the growth of nonagricultural employment and the urban unemployment levels. Part of the problem has to do with definitions of employment, part-time employment, unemployment, etc., and the way that surveys collect these data. Experience with the population model indicates that more work is required in this area.

FOOTNOTES

[1] At present, the number of full-time, active, universal military service personnel in the Republic of Korea is in excess of 600,000 men. Male military conscription is fully enforced in Korea, and men become eligible for conscription at age 20. Although the standard period of service is three years, most conscriptees are discharged after 32-33 months of active duty. Between 1960 and 1970 the proportion of each male five-year cohort in active military service did not change much and the size of the military grew with the growth of the eligible population. In the early 1970s, however, the eligible population apparently began to grow faster than the planned expansion of military strength. As a result a proportion of new conscriptees are presently being assigned after basic training to paramilitary service for a period of one year with the national police and other public security forces, followed by longer periods of service in reserve units.

[2] In mathematical/programming notation, the sequence of operations in the migration mechanism for each mode is,

<u>Mode 1: Exogenously Specified Overall Migration Rate</u>

$$TMIG_t = \sum_{sex=m}^{f} \sum_{age=1}^{85+} RUMV(age, sex)*POPC'_t(age, sex, farm) \quad (1)$$

$$RUMF_t = TRUM_t/[TMIG/POPC'_t(total, farm)] \quad (2)$$

<u>Mode 2: Labor Supply-Demand Mode</u>

$$CMIG_t(age, sex) = RUMV(age, sex)*POPC'_t(age, sex, farm) \quad (3)$$

$$EMPMIG_t = \sum_{sex=m}^{f} \sum_{age=1}^{85+} [CMIG_t(age, sex)*CIV_t(age, sex)*EAPMV(age, sex)* UEMPR_t] \quad (4)$$

$$UEMDEF_t = DLNV_t - FLN_t - UEMPR_t* \sum_{sex=m}^{f} \sum_{age=1}^{85+} EAPNV(age, sex)* CIV_t(age, sex)*POPC'_t(age, sex, nonfarm) \quad (5)$$

$$RUMF_t = UEMDEF_t/EMPMIG_t \quad (6)$$

Transfer of Migrants

$$MIG_t(age, sex) = RUMV(age, sex)*RUMF_t*POPC'_t(age, sex, farm) \quad (7)$$

$$POPC_t(age, sex, farm) = POPC'_t(age, sex, farm) - MIG_t(age, sex) \quad (8)$$

$$POPC_t(age, sex, nonfarm) = POPC'_t(age, sex, nonfarm) + MIG_t(age, sex) \quad (9)$$

where:

CIV = proportion of a cohort, which is civilian, civilians per capita or civilians per migrant

CMIG = *ex ante* estimate of net number migrating from a farm cohort, migrants per capita-year

DLNV = total nonagricultural labor demand, laborer-year per year

EAPMV = proportion of migrant cohort which is economically active, economically active persons per migrant

EAPNV = proportion of a civilian nonfarm cohort which is economically active, economically active persons per nonfarm civilian

EMPMIG = *ex ante* estimate of total employed migrants, laborer-year per year

FLN = net off-farm employment (labor from farm households employed in the nonfarm sector), laborer-year per year

MIG = *ex post* estimate of net number migrating from a farm age-sex cohort, migrants per year

POPC = number of people in an age-sex cohort after migration, per capita

POPC' = number of people in an age-sex cohort before migration, per capita

RUMF = uniform adjustment coefficient for RUMV, dimensionless

RUMV = nominal profile of net proportion of a farm population age-sex cohort migrating, migrants per capita-year

TMIG = *ex ante* estimate of the total number of migrants, migrants per year

UEMDEF = *ex ante* estimate of the deficit between labor demand and labor supplied by off-farm employment and the nonfarm population, laborer-year per year

[3] Efficiency in migration is the ratio of the net exchange of population to the total two-way flow, and ranges from zero, when the flows exactly cancel out; and to one, when all movement is in one direction and the number of net migrations is exactly equal to the number of gross migrants.

[4] Primary sources include F.A.O. Korean Association, Human Nutrition Requirements in Korea, Recommendations by Ministries of Health and Social Affairs and Science and Technology, in cooperation with the Korean Nutrition Institute, 1975. The calorie recommendations, in turn, were based on (a) Report of a Joint FAO/WHO Ad Hoc Expert Committee, "Energy and Protein Requirements," FAO Nutrition Meetings Report Series No. 52 (Rome: FAO, 1973); and (b) World Health Organization, "Handbook on Human Nutritional Requirements," WHO Monograph Series No. 61 (Geneva: World Health Organization of the United Nations, 1974).

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CHAPTER 9

THE NATIONAL ECONOMY COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

Michael H. Abkin

Rationale

The agricultural sector in Korea, as in any country, is an integral part of the national economy. Figure 1 highlights two major classes of interactions between the agriculture/farm and nonagriculture/nonfarm sectors of a nation's socioeconomy: demands for each other's products and competition for factor inputs. Classes of interactions not shown would include, among others, ecological and recreational influences (see Chapter 2).

The implication in Figure 1 that farm is equivalent to agriculture and nonfarm is equivalent to nonagriculture is merely a simplification for demonstration purposes. Farm households frequently supplement their income through nonagricultural employment during slack seasons. In Korea, about 18 per cent of farm income derives from such sources, and a major rural welfare objective of the Korean government is to increase that nonagricultural contribution to about 26 per cent during the Fourth Five-Year Plan period, ending in 1981. Similarly, although to a lesser degree, nonfarm household income may be augmented from agriculture through, for example, sharecropping and tenant farming.

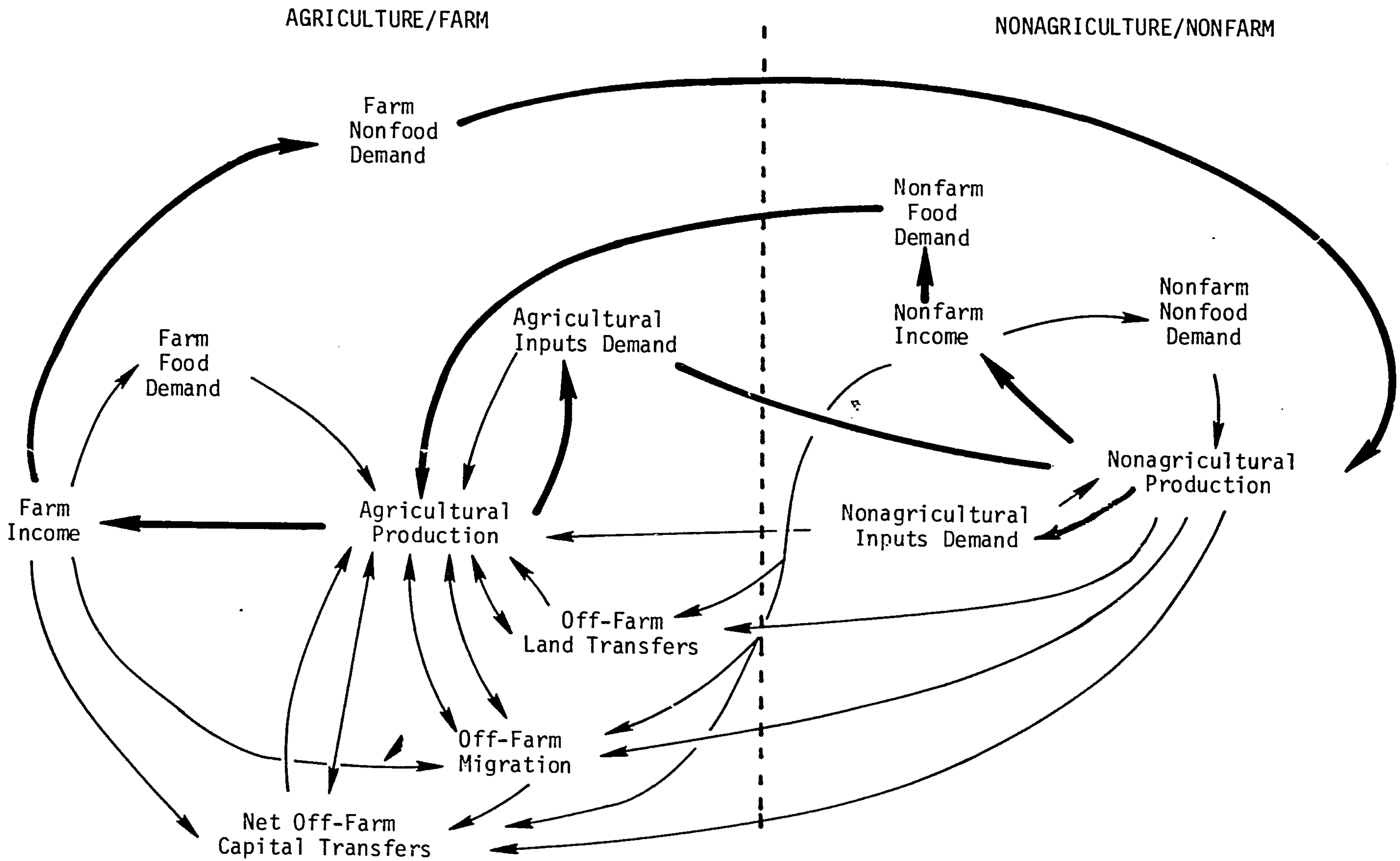

Figure 1. Major Intersectoral Linkages between Agriculture/Farm and Nonagriculture/Nonfarm

On the demand side, the upper part of Figure 1, are two of the strongest feedback loops between agriculture and nonagriculture (emphasized with thick arrows in the figure). Both of them are positive loops in that increases in agricultural production, say, lead to increases in nonagricultural production, which feed back to further stimulate agriculture. For example, agricultural growth resulting from public investments in land and water development programs and crop improvement research and extension can increase farm income and, hence, farm consumer demand for nonagricultural goods and services. In addition, demand for agricultural inputs will also rise to support the increased production levels. Both of these demands--for intermediate and capital inputs and for consumer goods and services--will stimulate increases in nonagricultural production to satisfy them.[1] Nonfarm income and, hence, demand for food will rise accordingly, providing a further stimulus for agricultural growth. Nonagricultural growth also has a positive impact on agriculture through increased demands for industrial raw materials.

The competition for factor inputs is diagrammed in the lower half of Figure 1, which emphasizes the feedback effects on agricultural production of losses of land, labor, and capital to nonagriculture. Land is transferred out of agriculture to satisfy the needs of an expanding industrial sector and to be used for residential construction for a growing population, the latter demand being influenced by income, as indicated in Figure 1. In Korea, a land-poor country, arable land has been leaving agriculture at the rate of about 13 thousand hectares per year. Without investments to increase the productivity of the remaining land or to reclaim new land, this can only have a negative impact on agriculture.

Agriculture also supplies labor required by a growing nonagriculture. The net effect on agriculture of off-farm migration--which in Korea is running at a rate of about 3 per cent of the farm population per year--is mixed. If the necessary capital and technology are available to allow mechanization to replace the lost human labor without a loss in production, the increased productivity of the remaining labor will increase farm income, which will have a positive impact on agricultural production, as we saw above. In addition, migrants frequently return a portion of their nonagricultural income back to agriculture, with capital transfers through their family members remaining on the farm. On the other hand, migrants who move simply to swell the ranks of the urban unemployed or underemployed will have a negative impact on nonfarm income and, hence, agricultural production through demand effects. Furthermore, migrants represent a drain on agricultural capital insofar as investment in their education was financed by agricultural production.

Finally, there is also a competition between agriculture and nonagriculture for capital resources. Figure 1 refers to *net* capital transfers, implying that the flow goes in both directions, unlike the predominant pattern of land and labor transfers. As noted above, migration itself represents capital leaving agriculture and also generates a flow of nonagricultural capital back home to the farm. Capital also flows out of agriculture in the form of taxes and savings deposits. If subsidies, credits, and public investments and services back to agriculture exceed this outflow, however, the net effect on the agriculture/farm sector can be positive.

The relevant question now concerns the relative strengths of these interactions and their implications for the design of agricultural sector analysis. One approach would be to consider in the analysis only the impacts on agriculture of nonagricultural sector variables (e.g., nonfarm income), ignoring the feedback effects of agriculture on those variables. If the implicit assumption in this approach that any such feedback effects are negligible is realistic, this approach is justified. On the other hand, if agriculture does significantly affect nonagriculture--and hence nonfarm income, for example--then the analysis must also consider the relevant causal linkages from agriculture to nonagriculture.

In Korea, the elasticity of nonagricultural production with respect to agricultural production in 1970 has been estimated to be .295. Conversely, the elasticity of agricultural production with respect to nonagricultural production was .854 in 1970.[2] For purposes of partial analysis of agricultural subsectors, such as demand projections or livestock production planning, it may be justifiable to treat as exogenous nonagricultural variables which impact on the agricultural subsectors of concern. The above elasticities imply, however, as rough a measure as they are, that comprehensive sector analyses of the consequences of agricultural policies and programs can treat nonagricultural variables as exogenous *only* at the risk of losing information important to public decision-makers on the potential impacts on the nonagricultural economy of those policies and programs and the consequent secondary impacts on agriculture itself. For example, the product of the above elasticities says that such secondary impacts can be as much as 25 per cent of the primary impacts.

This chapter describes the national economy component (NECON) of the Korean Agricultural Sector Model (KASM). The next two sections define NECON in terms of (1) its linkages with other KASM components and (2) its own internal structure. The following two sections discuss data requirements and model testing, and we conclude with a discussion of areas for further research and model development.

NECON Boundaries

The boundaries of NECON are defined by its inputs and outputs. These are described in three categories-linkages with the rest of KASM, policy inputs, and other inputs and outputs-as shown in Figure 2.

Linkages in KASM

The national economy component interacts with the production, demand, and population components of KASM.[3] NECON's strongest ties are with DEMAND. Nonfarm income affects the income response and budget constraint in the consumption functions in DEMAND (see Chapter 12). The aggregate price index of nonfood commodities helps determine expenditures on nonfood goods and services. These are fed back to NECON where they are disaggregated by nonfood sector as a component of final demand. Finally, agricultural trade is used in NECON for the trade accounts and agricultural exports become part of final demand.

Agricultural input price indices are used in the production component of KASM in the determination of yields and input application

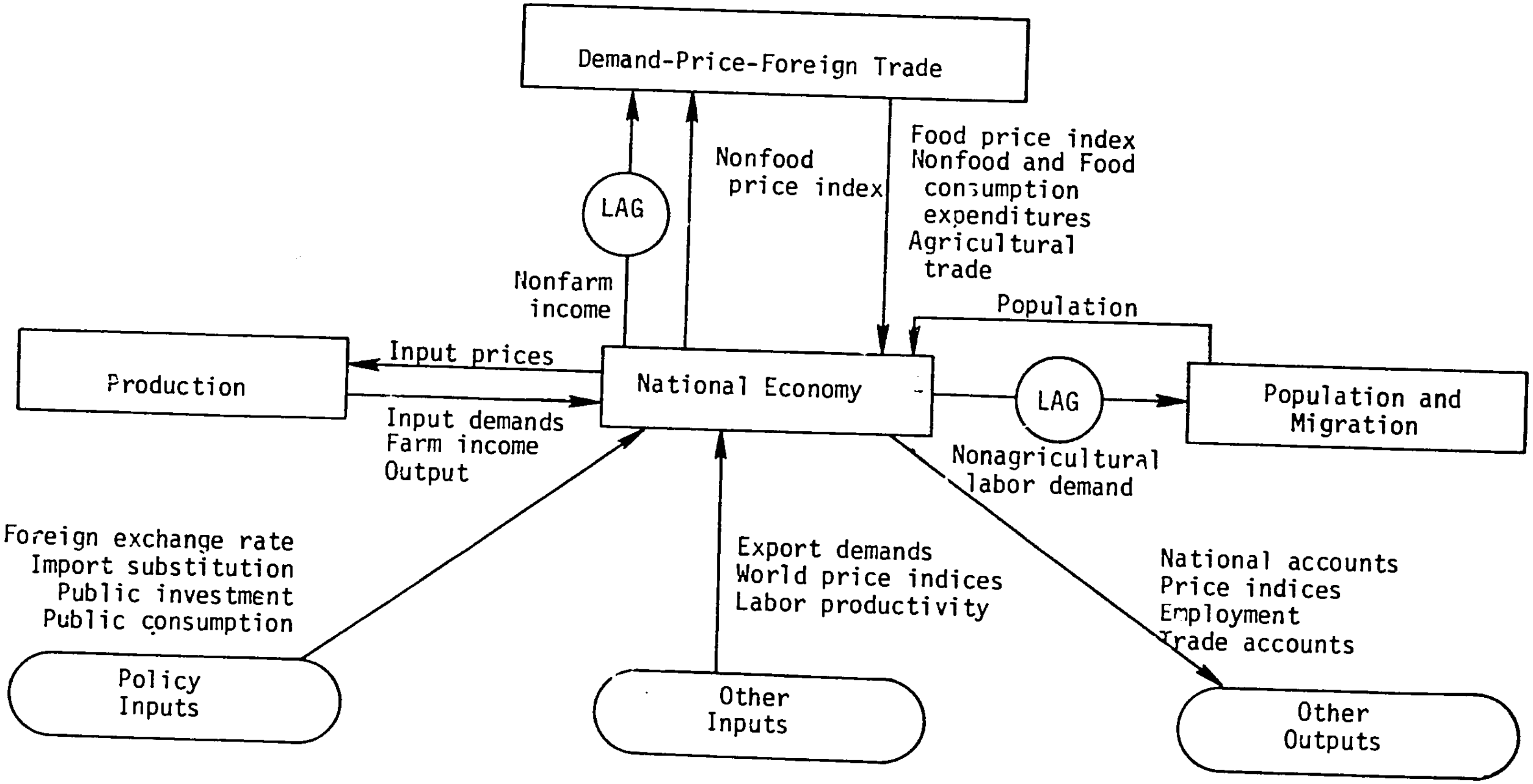

Figure 2. Major Linkages between the National Economy Component and the Rest of the Korean Agricultural Sector Model

rates (Chapter 10) and resource allocation decisions (Chapter 11). In return, intermediate input demands and agricultural output are used by NECON to modify the coefficients in agriculture's column of the input-output technology matrix. In addition, agriculture's demands for investment goods are part of final demand for the capital goods-producing sectors of NECON.

Finally, NECON uses projections of farm and nonfarm populations in its consumption subcomponent and to compute per capita values of accounting variables. NECON's projections of labor requirements in the nonagricultural sectors are used by the KASM population component (POPMIG) as a driving force for farm-nonfarm migration.

Policy Inputs to NECON

Five policy instruments may be investigated with NECON. Since KASM is concerned with agricultural sector analysis, none of NECON's policy inputs involves structural change in the nonagricultural sectors.

Alternative levels of won-dollar foreign exchange rates may be projected over time as a policy input. NECON will show the effect of this policy on the won value of foreign trade accounts. Since export demands are projected for each sector in dollar terms, any effect changes in the exchange rate might have on the dollar value of exports would have to be analyzed outside the model, if desired, and fed into NECON as new export demand projections. Similarly, on the import side, the effect of alternative exchange rates on domestic demand for intermediate inputs and consumer goods would be done off-line and result in changes in the import coefficients used in the model.

Various tax rates may also be specified by policy assumption in NECON. These include income tax rates for farm and nonfarm households separately, indirect tax rates for each sector, and import tariffs for each sector.

Government policies to promote import substitution may also be tested. Import substitution coefficients are computed for investment goods, consumer goods, and intermediate inputs. These computations reflect exogenous assumptions as to the achievement of target import substitution levels, without regard to *how* these levels might be achieved. Thus, NECON can address such questions as, What would be the consequences of achieving target import substitution levels? but not how the government might achieve them. Finally, public investment in each sector and public consumption of each sector's output are projected as policy inputs to NECON.

Other Inputs and Outputs

As mentioned above, the dollar value of exports for each sector is projected over time outside the model for use by NECON. These exogenous projections may be based on trade analyses of Korea's potentials in world markets or merely on assumed policy targets. World and domestic producer price indices for each sector are similarly projected.

Changes in labor productivity in each sector are computed by NECON, based on exogenous assumptions of ultimate values of labor productivity and of the speed with which those targets will be reached. These productivity projections affect the nonagricultural labor requirements which feed back to KASM's population component to determine off-farm migration.

In addition to outputs of NECON which go to other KASM components, NECON computes other performance criteria for use in evaluating model performance. Some of these include national accounts (total and per capita GDP and income, profits, wages, value added), sector-specific market price indices, employment in each sector, and foreign trade accounts.

Structure of NECON

The national economy component is basically a recursive input-output model of the Korean economy, where the recursion takes place via the linkages (discussed above) with the rest of KASM. In general, farm income, agricultural production, part of the final demand vector which drives the input-output (IO) production model, and part of the IO technology matrix are determined in the agricultural sector model. Likewise, nonfarm income and agricultural input prices, important drivers of food consumption and agricultural production, respectively, are determined in NECON.

NECON disaggregates the economy into 16 sectors. The behavior of the first sector, agriculture, is an aggregation of the behavior of the agricultural sector as projected in detail by KASM. Table 1 relates NECON's 16 sectors to the Bank of Korea's 56-sector classification [2]. This 16-sector classification emphasizes the major agricultural intermediate input and investment good industries: chemical fertilizers, machinery, fuels, and construction. Pesticides are included in the "other chemicals" sector.

Table 1. Korean Sectoral Clarifications

Korean Agricultural Sector Study 16 Sectors		Bank of Korea 56 Sectors
1. Agriculture	AG	1. Rice, barley, and wheat (polished) 2. Vegetables, fruits, and other grains 3. Industrial crops 4. Livestock breeding and sericulture 6. Fishery products
2. Forestry	FOR	5. Forestry products
3. Mining	MIN	7. Coal 8. Metallic ores 9. Nonmetallic minerals
4. Chemical fertilizers	CHF	26. Chemical fertilizers
5. Other chemicals	OCH	24. Inorganic chemicals 25. Organic chemicals 27. Drugs and cosmetics 28. Other chemical products
6. Machinery	MA	37. Nonelectrical machinery 38. Electrical machinery 39. Transportation equipment
7. Fuels	FU	29. Petroleum refining and related products 30. Coal products
8. Other heavy manufacturing	OHM	20. Lumber and plywood 21. Wood products and furniture 22. Paper and paper products 31. Rubber products 32. Nonmetallic mineral products 33. Iron and steel 34. Primary iron and steel products 35. Nonferrous metal ingot and primary products 36. Fabricated metal products
9. Food processing	FP	10. Slaughtering, dairy products, and fruit processing 11. Canning and processing of sea foods 12. Grain polishing and milling 13. Other food preparations 14. Beverages 15. Tobacco
10. Textiles	TX	16. Fiber spinning 17. Textile fabrics 18. Apparel and fabricated textile products
11. Other light manufacturing	OLM	19. Leather and leather products 23. Printing and publishing 40. Measuring, medical, and optical instruments 41. Miscellaneous manufacturing
12. Trade	TRD	50. Wholesale and retail trade
13. Transportation and storage	TS	49. Transportation and warehousing
14. Construction	CON	42. New buildings and maintenance 43. Public utilities and other construction
15. Utilities	UT	44. Electric utilities 45. Water services 48. Communications
16. Other services	OS	46. Financing and insurance 47. Real estate 51. Government services 52. Social services 53. Other services 54. Office supplies 55. Business consumption 56. Unclassifiable

The internal structure of NECON is diagramed in Figure 3. Exogenous inputs and outputs of each of the six subcomponents shown in Figure 3 are classified according to whether they represent (1) linkages with the rest of the agricultural sector model (KASM), (2) policy inputs, or (3) other exogenous inputs and performance criteria outputs. Brief descriptions of each of the six components follow.

Consumption

The consumption subcomponent computes private per capita and total demand for domestic and imported consumer goods.

The food consumption component of KASM (Chapter 12) projects farm and nonfarm demand for 19 agricultural commodities and one aggregate nonagricultural commodity. In order to maintain consistency under sequential (rather than simultaneous) solution of the two consumption components (KASM's and NECON's), we assume all interaction between food and nonfood demand (i.e., via cross elasticities) takes place in the food demand model of KASM. In NECON, then, the aggregate nonfood consumption expenditure computed in KASM for farm and nonfarm consumers is disaggregated among the 14 nonfood sectors.

For each class of consumers, farm and nonfarm, the private consumption function is of the same form as the food demand model (Chapter 12).

$$C(t) = C_0[f\{P(t), X(t), G(t)\}]^{S(t)} \qquad (1)$$

where C is a vector of per capita consumption in each nonfood sector, P is a vector of price indices, X is total per capita nonfood consumption

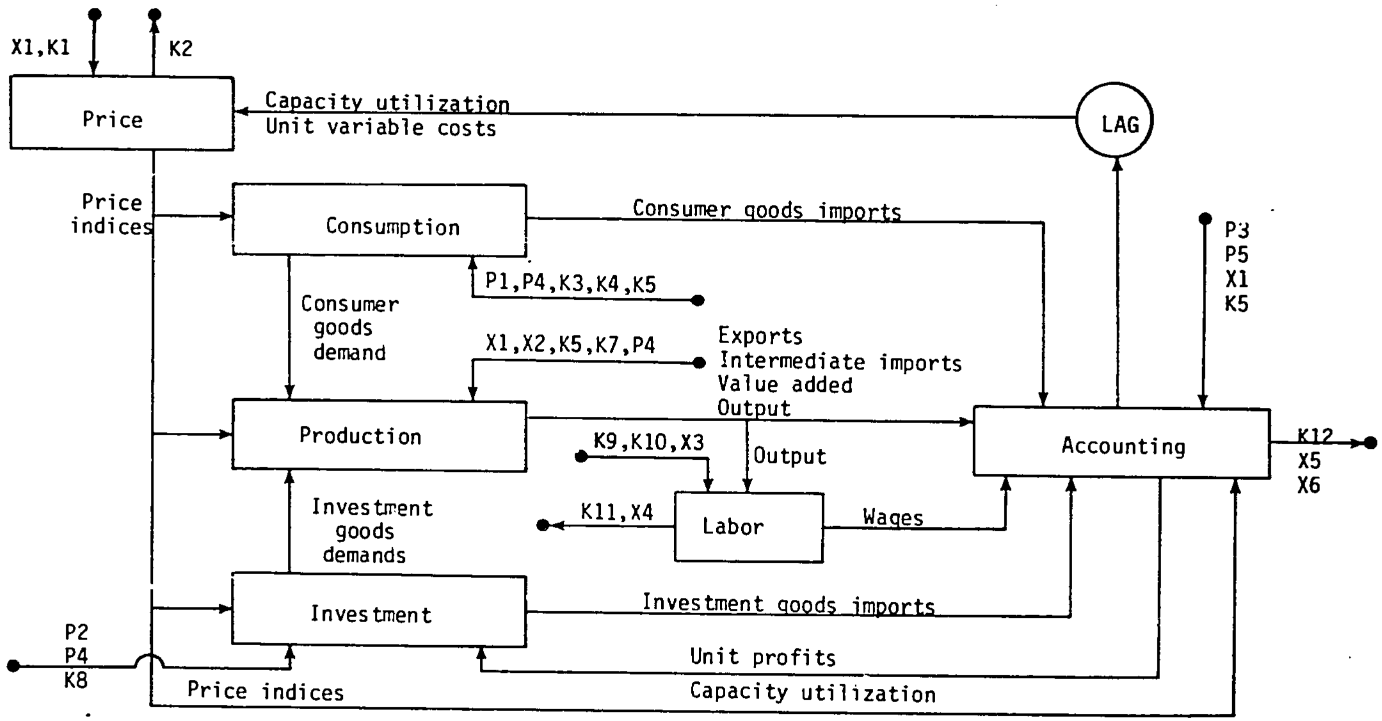

Figure 3. Internal Structure of NECON

KEY TO INPUTS/OUTPUTS

KASM Inputs/Outputs

K1-Food prices
K2-Agric. input prices
K3-Food consumption
K4-Total nonfood consump. expenditures
K5-Population
K6-Agric. exports
K7-Agric. input demands
K8-Agric. investment
K9-Agric. employment
K10-Agric. wages
K11-Nonagric. labor requirements
K12-Disposable income

Policy Inputs

P1-Public consumption
P2-Public investment
P3-Foreign exchange rate
P4-import substitution
P5-Tax rates

Other Inputs/Outputs

X1-World price indices
X2-Export demands
X3-Labor productivity
X4-Employment
X5-National income accounts
X6-Trade accounts

expenditures, G is per capita gross domestic product, and S is an elasticity expansion parameter computed by the model to force the budget constraint (see below). Gross domestic product is included as a measure of national development and modernization, which was found to be significant in explaining consumption levels in certain sectors; namely, transportation, utilities (which includes communications), and other services.

The function f in equation (1) is of Cobb-Douglas form, where the exponents of P, X, and G are elasticities--hence, the term "elasticity expansion parameter" for S. S is a number, nominally of unit value, which is computed to insure the budget constraint, where the constraint is total nonfood expenditures computed in the food demand component of KASM. That is,

$$P^T C = X \tag{2}$$

must hold at each point in time.

Total consumption demand for each sector is computed by multiplying per capita demand by population and adding public consumption. Consumption is disaggregated into demands for domestically produced and imported consumer goods using import coefficients which vary over time according to import substitution policies.

Investment

The investment component computes net and gross investment, demands for domestic investment goods, and investment goods imports. The proportional rate of change of private net investment in nonagricultural sectors (except residential construction which is a separate function of income and population) is postulated to be a function of the proportional rates of change of profits per unit output and of capacity utilization. In Cobb-Douglas form,

$$I_i(t) = I_{i0}R_i(t)^{\alpha_i}U_i(t)^{\beta_i} \tag{3}$$

for each nonagricultural sector i. Investments in agriculture are computed in KASM. In equation (3), I is private investment, R is profits per unit output, U is a measure of capacity utilization, and α and β are elasticities.

Equation (3) postulates that changes in private net investment are driven by changes in profits per unit output and by changes in capacity utilization (measured indirectly as discussed below). Modeling, thusly, the causal basis of net investment is an attempt to avoid some of the problems associated with modeling current investment (per common practice [8, 9]) as a function of future changes in output; i.e., what investment must be at time t to enable a change in output at time $t+\tau$, where τ is a gestation lag. One theoretical and practical problem with this approach is the use of changes in actual output rather than capacity output.

There is general agreement that capacity output would be the proper concept to use, but difficulties in defining and measuring it reliably [10] have led to the use of actual output in its place. In NECON, however, we have tried to measure proportional changes in capacity utilization indirectly as proportional changes in output per unit capital stock (instead of per unit capacity output). This is not an unreasonable measure if the ratio of capacity output to capital stock can be assumed to be constant. While equation (3) may be adequate for NECON's purposes, the relationship of investment to capacity utilization is the subject of much needed advances in investment/disinvestment/user cost theory which takes explicit account of the rate of utilization of capital services [3].

After computing private net investment, NECON adds public investment and replacement investment (assumed equal to depreciation) to private net investment to calculate gross investment. Using the B matrix, investment in each sector is translated to demands for investment goods from each sector. Using import coefficients which depend on import substitution policies, investment demands are split into demands for domestically produced and imported investment goods. Finally, in the computation of capacity utilization, capital stock in each sector is the integral over time of net investments, allowing for investment gestation lags.

Production

Based on final domestic demand, the production subcomponent computes output and unit value added for each sector. Final domestic demand for each sector's output is the sum of domestic consumption, investment good demand, and exogenous projections of export demand. As a simplification, inventory changes do not appear in the final demand vector. In 1970, only about 1.5 per cent of total output went to inventory changes. This assumption can be changed, if necessary, without too much difficulty, since inventory coefficients do exist [7, 9].

Constraints on production--particularly capacity constraints and skilled labor constraints--are not directly considered in the model.

The primary purpose of NECON--to link agriculture with nonagriculture, rather than to project and analyze Korean industrial development--does not justify the increased complexity and costs of a constrained model; e.g., some kind of programming algorithm for the production component, a population component disaggregated by skill level, and direct measurement of capacity. However, NECON does address the capacity problem indirectly by making private net investment a function of capacity utilization.

For its purposes, NECON assumes the input-output coefficients for the 15 nonagricultural sectors (at constant relative prices) will not change over the time horizon of the model. Although this is certainly an unrealistic assumption, it is beyond the scope of NECON to project changes in the technological interdependence of Korean industry. If such projections are done by other researchers and made available, they can be incorporated into the model. In the meantime, results of *agricultural* analyses should be interpreted in light of this assumption that nonagricultural technology will not change or will change only in such a way as to leave the input-output coefficients unchanged. The fairly high degree of aggregation (16 sectors) will tend to reduce the errors introduced by this assumption relative to what they would be in a more disaggregated model. In addition, NECON does consider the effects of changes in relative prices and of import substition policies.

The input-output coefficients for agriculture, on the other hand, will change in the model based on KASM projections of input demands and agricultural output. For the current version of KASM, coefficients are changed over time only for chemical fertilizers, other chemicals, fuels, other heavy manufacturing and other light manufacturing. The 1970 Bank of Korea coefficients are maintained for the other agricultural inputs and for the coefficients of the other sectors.

In matrix notation, output is

$$OUT(t) = [I\text{-}AD(t)]^{-1}FDD(t) \tag{4}$$

where OUT is the vector of sector outputs, I is the identity matrix, FDD is the final domestic demand vector, and AD is the matrix of domestic intermediate input requirements per unit output. AD is computed to account for import requirements and relative price changes. Finally, the production subcomponent computes value added per unit output and imports of intermediate inputs, the latter based on import coefficients resulting from import substitution policies.

Labor

The labor subcomponent computes labor requirements and wages by sector and for nonagriculture in the aggregate. Agricultural employment and wages are determined in the agricultural production component of KASM.

Labor productivity in each sector is assumed to increase asymptotically to an upper limit. Actually, NECON models the converse of this; i.e., labor requirements per unit output decrease asymptotically to a lower limit (Figure 4). For each sector i,

$$\frac{dL_i(t)}{dt} = \frac{1}{\tau_i}[FL_i - L_i(t)] \tag{5}$$

where L is employment per unit output, FL is the limiting value of L,

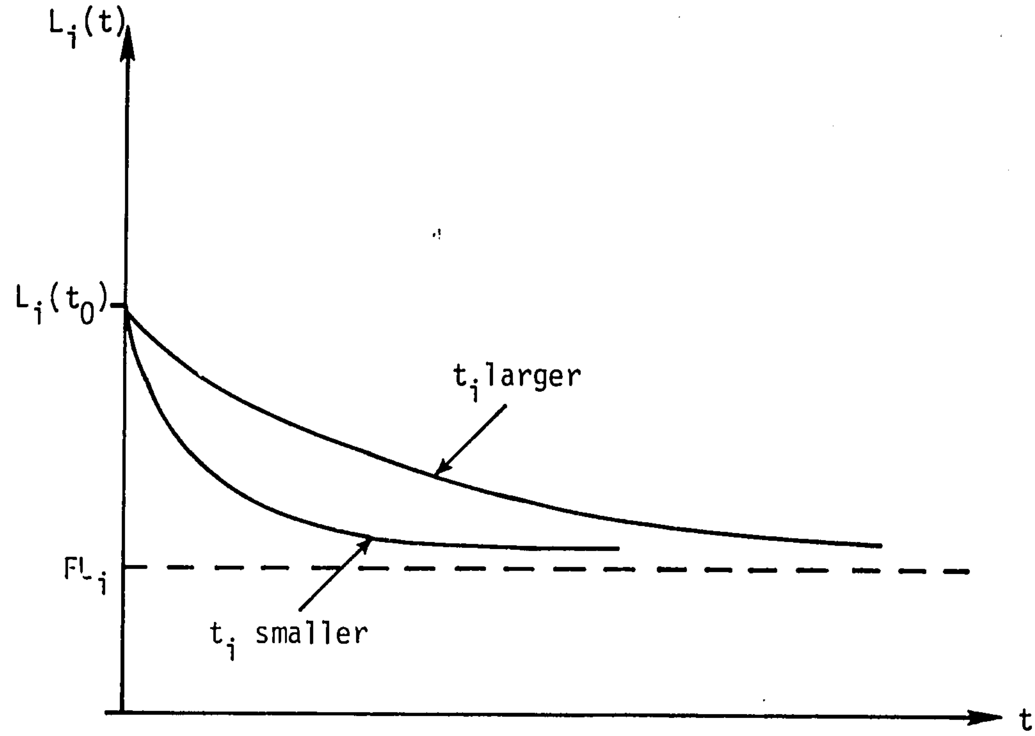

Figure 4. Projection of Unit Labor Requirements

and τ is a time constant which determines the speed with which L approaches FL.

Wages (including salaries, bonuses, etc.) are projected, assuming real wages per unit output tend to be constant. Again, it would be easy to make other assumptions; however, it is beyond the scope of NECON to project nonagricultural wages endogenously as a function of other economic variables in the model. This would require a much more complex employment model.

Price and Accounting

The price component generates market price indices for nonagricultural sectors based on exogenous projections of producer price indices, world price indices, and trade and transportation margins. Price indices of the agricultural and food processing sectors depend on food prices determined in the demand component of KASM (Chapter 12).

While domestic market price indices depend on producer price indices and trade and transportation margins, the consumers' market price indices and the investors' price indices are weighted averages of the domestic market price indices and the world price indices, where the weights used are the consumer goods and investment goods import coefficients, respectively. In addition, the price component computes agricultural input price indices needed by the production components of KASM and the aggregate nonfood price index used in the demand component of KASM.

The accounting component computes national accounts and other economic variables needed in other components of NECON, in KASM, and as measures of system performance. These include total and sector-specific value added and its components, total and per capita nonfarm income, agricultural and nonagricultural income, unit profits for the investment functions, trade balance, tax revenues, and gross domestic product.

Data Requirements

The data needs of any model fall into three categories: initial conditions, constant parameters, and policy parameters. Also required to run a model are projections of the exogenous input variables. The categories are not distinct in that policy parameters overlap the other categories; i.e., some are initial conditions, others are constant coefficients, and still others may be exogenous projections over time. Data needs of the national economy model (NECON) will be discussed by subcomponent, in the same order as in the last two sections.

Inputs to NECON

There are three sources of inputs to NECON: KASM, policy assumptions, and exogenous projections. These have been discussed earlier in this chapter so will not be repeated here. It is sufficient to point out that if NECON is used independently of one or more KASM components from which it requires inputs, those inputs would have to be supplied exogenously.

Consumption

Constant parameter data requirements of the consumption subcomponent include--for farm and nonfarm consumers and for 11 of the 16 sectors[4]--own- and cross-price elasticities, expenditure elasticities, and elasticities with respect to GDP. These elasticities have been estimated for nonfarm consumers based on time series compiled from urban household surveys [4] and price surveys [5]. Estimation for farm households has been difficult since farm household surveys [11], until just recently, have not collected consumption data at a level disaggregated enough to permit reaggregation under NECON sector definitions. For the time being, therefore, NECON uses nonfarm elasticities for both consumer groups. Additional constant parameters required for the consumption subcomponent are trade and transportation margins for consumer goods. These are derived from Bank of Korea (BOK) input-output data [2].

Initial conditions required are (1) per capita consumption expenditures for farm and nonfarm consumers in each of the 11 nonfood sectors and (2) the budget constraint elasticity expansion parameter. The former are derived from household surveys [4, 11], and the latter is initialized at its nominal value of unity. In addition, initial total and noncompetitive consumer good import coefficients are required for each sector. These have been derived from input-output data [2].

Investment

The investment subcomponent of NECON requires constant parameter data, for each of the 15 nonagricultural sectors, on profitability and capacity utilization elasticities of private net investment. For the mining and manufacturing sectors, these elasticities were estimated from time series derived from the Mining and Manufacturing Surveys [6]. Data for population and income elasticities in the residential construction investment function must also be supplied. These have also been estimated from time series data [1].

The B matrix, which converts investment by sector of destination into demands for investment goods by sector of origin, is computed in NECON, based on incremental capital-output ratios (ICORs) and relative prices. The matrix of ICORs, by sector of origin and sector of destination, must be supplied as constant parameters. These have been estimated for the NECON sectors from (1) the K. C. Han study [7] of capital coefficients, based on the 1968 wealth survey, and (2) an aggregation of the KDI 52-sector model [9]. Additional constant parameters required are trade and transportation margins for investment goods for each sector and lag times for investment gestation delays. The margins have been derived from input-output data [2].

Initial conditions required for the investment subcomponent are residential construction investment, private net investment, and capital stock in each sector. In addition, initial total and noncompetitive investment-good import coefficients are required for each sector. These have been derived from input-output data [2].

Production

Two sets of constant parameters are needed as data for the production subcomponent. Trade and transportation margins for exports of each sector are derived from input-output data [2], as are the interindustry input-output coefficients (except agriculture). Input coefficients for agriculture are computed by NECON, based on information from the agricultural sector model.

As initial conditions, total and noncompetitive intermediate input import coefficients, by sector of origin and sector of destination, are required. These have also been derived from input-output statistics.

Labor

Constant parameters needed to run the labor subcomponent are, for each sector except agriculture, the limiting values of unit labor requirements and the time constants governing the decay rate towards those limits (FL and τ in equation (5)). Also required for each sector are the proportions of total employment which is wage labor. Data from the Mining and Manufacturing Surveys [6] and input-output statistics [2] were used to estimate these parameters. Initial conditions of unit labor requirements and wage rates for each sector were derived from the same sources.

Price

Constant parameters required for the price subcomponent are, for each sector, trade and transportation margins for consumer goods, investment goods, and agricultural inputs. These have been derived from input-output statistics [2]. In addition, exogenous projections of producer and world price indices are needed. All price indices are initialized to unity in the model.

Constant parameters which must be estimated for the accounting subcomponent are capital consumption allowance and indirect taxes per unit output for each sector (estimated from input-output data [2]) and income and import tax rates.

Variables which must be initialized are real gross domestic product for each of the ten years preceeding the initial year. The latter are used in computing one-year, five-year, and ten-year average growth rates of GDP.

Preliminary Testing and Areas for Further Research and Model Development

Preliminary testing of NECON, independently and linked with the rest of KASM, has indicated several areas of further research and model development. The most important areas fall into three broad categories: price projections, private investment projections, and consistency of KASM linkages.

In earlier stages of model development, NECON attempts to project real (i.e., deflated) producer price indices for each nonagricultural sector. Problems arose in doing this, because the deflated price index is not just a function of costs and capacity utilization, as was postulated, but also the general price level as well; i.e., all other prices. To project nominal price indices, however, would require consideration of the effect of government monetary and fiscal policies on the general level of demand, clearly beyond the scope of KASM. Or at least an exogenous variable, perhaps a time-trend factor, could be added to disposable income and/or public consumption to reflect that effect. Prices would then respond to the increased demand through the capacity utilization factor.

Another alternative--the one we have followed in the current model version--would be either to assume real price indices remain constant after the tracking period of the model (1970-1975) or to project sector-specific price indices exogenously. In fact, however, relative prices have *not* remained constant in the past. Furthermore, to continue 1975 price indices as constant would be to project an abnormal condition, in that the transient effect of the oil price shocks of 1973-1974 would be maintained, instead of allowing the system to adjust towards a new equilibrium or "normal" condition. Clearly, the question of whether price indices can or should be projected endogenously or exogenously bears further investigation.

Work that needs to be done with the private investment functions (see equation (3)) mainly involves tuning the elasticities, primarily the capacity utilization elasticities, so that investment in new capacity keeps pace with demand increases. Remember that there is no direct capacity constraint on production, but that net investment responds to capacity utilization (measured as the output-capital stock ratio). Assuming, as we do, that the ratio of *capacity* output (not actual output) to capital stock is constant, capacity utilization should stay close to its initial (1970) value or increase some, if capacity was underutilized in 1970. For some sectors, in preliminary tests, this is so; but for others capacity utilization projected by NECON increases two to three, sometimes five, times over ten years, indicating the need for a faster rate of investment in the model for those sectors.

Finally, when NECON is run linked with the rest of KASM, inconsistencies have become apparent between the microeconomic initial conditions for agriculture in KASM and the macroeconomic initial conditions for the agricultural sector in NECON. The latter are used when NECON is run independently, and the former are used when it is run linked with KASM. The result is that NECON behaves differently when run in the two modes. These problems are mainly related to exports, consumption of agricultural products, and agriculture's input-output coefficients and arise, at least partly, from the use of different sources for each set of initial conditions. KASM uses household surveys customs data, and food balance sheets to initialize consumption and exports, while NECON is initialized from 1970 input-output data and national accounts. Further investigation is required to account for the discrepancies, so that they can be reconciled.

FOOTNOTES

[1] This assumes, of course, that demand increases will, except possibly in the very short term, be supplied domestically rather than from imports.

[2] Derived from 1970 household survey [1, 2] and input-output data [3] and considering only interactions of intermediate input and consumption demands.

[3] In Figure 2, the production component is an aggregation of the technology change and resource allocation components.

[4] Of the other five sectors, consumption in two (agriculture and food processing) is determined in the KASM demand component, and final consumption of the other three (chemical fertilizer, trade, and construction) is assumed to be zero.

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CHAPTER 10

THE TECHNOLOGY CHANGE COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

Jeung Han Lee

Introduction

The technology change component (CHANGE) deals mainly with farmers' production decisions in response to changes in technology. More specifically, it models the processes determining how productivities or yield levels of crops under consideration change over time. These variables are determined in the real world by many different forces. The component focuses on the impacts of alternative public policies, programs, and projects.

The principal purposes of a sector model are (1) to capture the most important structural and behavioral relationships within the sector concerned and between it and the rest of the economy and (2) to help design development plans for the sector [16]. Indeed, the public sector has been the leading force in economic and social development of the Korean economy. And this will still be true in the future. Technological, institutional, and human changes toward modernization of the farm economy in Korea are mainly generated through public policies, programs, and projects. For the sector model to be more potentially useful in planning, it should clearly define how the specific, individual public policies, programs, and projects influence farmer decisions in allocating resources at their disposal and, hence, aggregate performance of the agricultural sector. CHANGE models dynamic interactions between the public and farm sectors with respect to resource-use intensity.

This component model has several objectives. The first is to identify the sources of productivity growth or development. The classical economist emphasizes only economic variables; the agronomist, biological variables; and the engineer, physical variables as means of accelerating economic growth and development. An integrated model is required which is comprehensive, consistent, and even optimal [18], with respect to all relevant variables. Individual factors are certainly not mutually exclusive; they may be economic complements to each other. It is important to identify the degree and extent of the interactions and contribution of individual factors to economic growth and development. Then economic development strategies can be designed in the context of the dynamic and long run, rather than the static and short run.

Another objective of this component model is to illustrate how different theories, techniques, decision models, and quantitative methods can be intermingled to deal with practical problems involving dynamics. It is difficult, if not impossible, to develop by a single quantitative method a comprehensive and consistent sector model dealing with the dynamic process of economic development. As indicated in other chapters, each component of KASM is modeled using a unique quantitative technique. This is also true for this component and for each subcomponent of this component model.

Lastly, as already implied, we intend to illustra with this component some methodologies to model the dynamic process of economic development more accurately and realistically. By the dynamic process, we mean the processes involving not only a time path of the variable concerned and a time lag or delay between causes and results, but also uncertainty (see [10] for the managerial process). More specifically, CHANGE models dynamically (1) the process of innovation diffusion (Abkin's model contains the process [1], (2) the process of land and water development, (3) the process of productivity growth or newly improved or developed land, and (4) the process of production decision-making.

Outputs of the Component Model

Let us now state more specifically what kinds of variables we intend to project over time as outputs of this component model. These include the following categories:

I. Individual crop yields by region

II. Factor inputs--intensity by crop and region

- A. Fertilizer inputs
- B. Chemical inputs
- C. Other material inputs
- D. Labor inputs
    1. Spring season
    2. Fall season
    3. Annual total

III. Agricultural land by region

- A. Total land area

1. Paddy
2. Upland
3. Potential double-crop land
4. Pasture land

B. Land areas improved by the land and water development projects by paddy or upland

1. Irrigation
2. Consolidation
3. Drainage
4. Reclamation
5. Other improvements

IV. Investment requirements for individual land and water development projects

Some model outputs, such as investment requirements, are final output. But most are intermediate variables needed to determine or project, directly or indirectly, the final performance variables of the global system of KASM. The major linkages between CHANGE and the rest of the KASM components, including the public sector, are shown in Figure 1. In relation to the overall KASM structure, CHANGE is most directly designed to provide input to the resource allocation and production component (FRESAL). That is, main CHANGE outputs of yield and factor inputs are designed to be inputs to either the objective function, input-output coefficients, or both of FRESAL. The land capacity outputs are designed to be inputs to the resource capacity of FRESAL, together with projections from other components, such as the farm labor force from POPMIG. Essentially, CHANGE is constructed to make FRESAL more completely dynamic and to link it with the public sector.

In addition, however, as seen in Figure 1, CHANGE supplies the national economy component (NECON) with (1) public and private

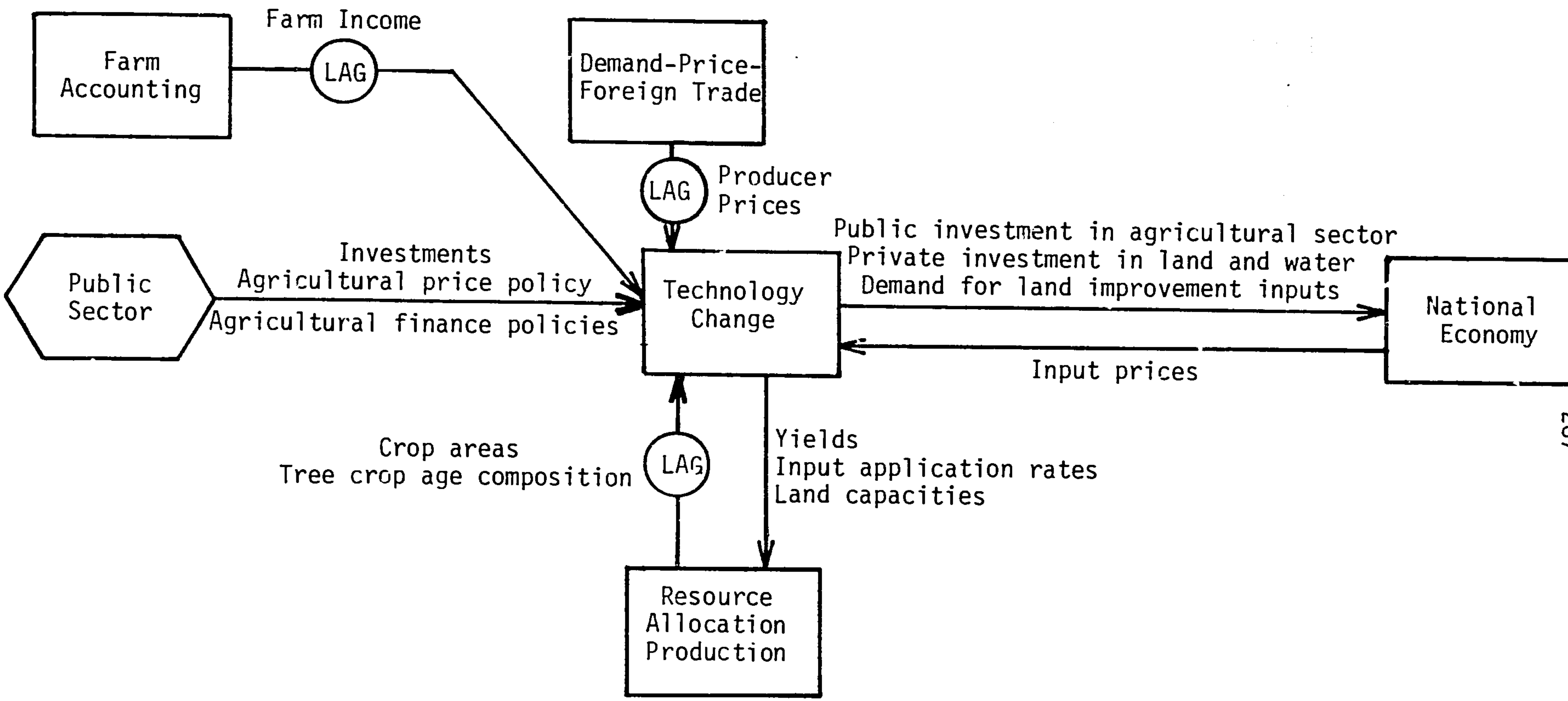

Figure 1. Major Direct Linkages between the Technology Change Component and the Rest of the Korean Agricultural Sector Model

investment made in the agricultural sector for land and water development, (2) demand for specific inputs required for land and water development supplied by the farm and nonfarm sectors, and (3) demand for the so-called "conventional" inputs required for farming and supplied from the nonfarm sector. That is, CHANGE projects factor input use per unit of land for individual crops. Thus, it is necessary to multiply this input application rate by the area allocated to each crop (determined in FRESAL) and then to sum the total input needed for each crop to project total demand for individual production factors, as required by NECON.

Inputs of the Component Model

What kinds of variables are likely to influence the output variables stated above? Or what kinds of instruments are available which the public sector is able or authorized to influence? The first two categories of the output variables indicated above are farmer decision variables, not public decision variables. Then how do public decisions affect these variables? Let us list the specific public policy instruments considered in this component model:

I. Policies related to land and water development

   A. Land and water improvement

      1. Multipurpose, large-scale, land development projects
      2. Large-scale irrigation projects for paddy
      3. Small-scale irrigation projects for paddy
      4. Paddy consolidation projects
      5. Paddy drainage projects
      6. Low productive paddy improvement projects
      7. Upland irrigation projects
      8. Upland consolidation projects

   B. Land reclamation

1. Tideland development projects
2. Upland development projects

C. Pastureland improvement program

D. Policies on agricultural land conservation

II. Policies related to biological technology development

A. Research program
B. Guidance program

III. Price policies

A. Product price policy
B. Factor price policy

IV. Agricultural finance policies

A. Credit program
B. Interest policies

These are the policy instruments available to the public planner. They are exogenously determined, as represented by a diamond in Figure 1. These are not claimed to be the only policies that the public sector can use to change the resource base and input-output coefficients for agricultural development. But they are considered most important, and they are directly related to productivity growth.

There are input variables other than policy inputs which affect productivity growth, directly or indirectly. By definition, these kinds of input variables must either be determined exogenously or supplied from other KASM components. The inputs to CHANGE which are generated as the output variables of other components are shown in Figure 1. Most of these inputs are not current, but one-year lagged variables (noted as LAG). This type of input includes (1) regional specialization (computed from crop areas), (2) change in tree crop age composition, (3) farm capital formation (computed from farm income), (4) producer prices, and

(5) factor input prices. Prices generated in DEMAND and NECON are supposed to be determined by market forces.

Other input variables are exogenously determined. In addition, there are variables generated within the component model as intermediate or state variables which relate input and output variables but are not considered part of component output. Some of these two types of variables will be discussed in the following section.

In summary, agricultural development has to do with technological, institutional, and human change. These changes, or transformations, basically are dependent on investment in agriculture. Both components, CHANGE and FRESAL, deal with investment problems on the production side. The former concerns itself mainly with public investment in the form of direct investment, subsidies, or finance, while the latter determines the level of farmer investment or capital formation for such items as farm machinery, livestock, perennial crops, etc.

Structure of the Component Model

Following is a discussion of how the output variables are projected, based on the model inputs indicated in the previous section. A simplified version of the model structure is shown in Figure 2. The component consists of five subcomponents, in addition to the public sector:

1. Land and water development
2. Biological research
3. Innovation diffusion
4. Factor demand projection
5. Product supply projection

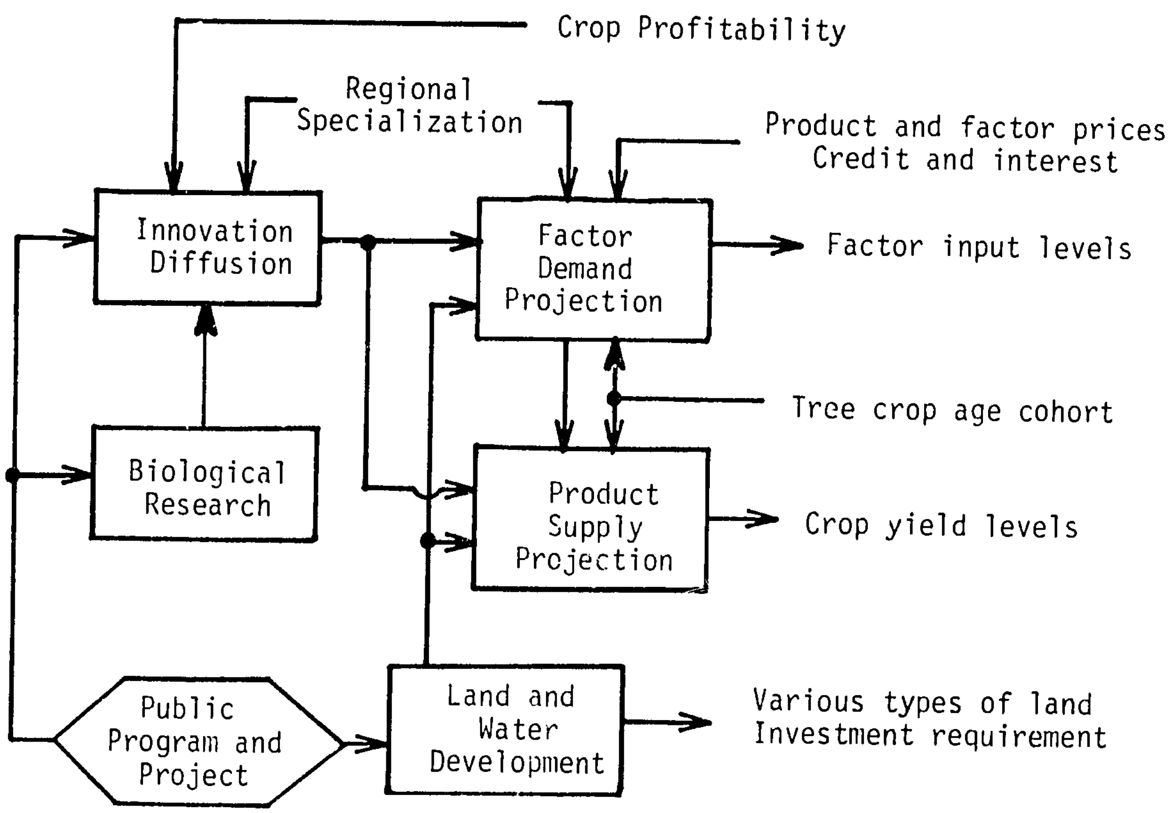

Figure 2. Internal Structure of the Technology Change Component

Product Supply Projection Subcomponent

First, for convenience, let us discuss the mechanism of individual crop yield projections. By explaining the final variables first and the causal variables last, we hope to increase reader understanding.

The production rate and, hence, supply, is exclusively a response to resource use. Thus, once the input rates are determined each year and the production function is known, it then becomes a computational problem to project individual crop yields. This is basically the production function approach. The price-output relationship, or supply function approach, is not used for several reasons. First, agricultural supply cannot be accurately explained with price variables alone. As shown in Figure 2, factor input levels (conventional as well as nonconventional) determine the production rate. Input and output prices affect output level through factor demand. But prices are only one of several kinds of variables which affect (conventional) factor demand. Secondly, regression approaches to supply analysis based on price-output relationships are known to be imperfect, especially when structural changes are present [12]. As a matter of fact, one of the primary objectives of an agricultural development plan is to change the input-output coefficients associated with agricultural production [5]. Much of this change can only be attained through technological, institutional, and human change; i.e., structural change. Third, positive price policy alone can do little to increase total farm supply, especially in the short run, from a low-level, stationary, equilibrium state. For most crops, the so-called "conventional inputs" in Korea are being used at the appropriate rates for maximum physical production [13], perhaps because of input price subsidy and credit programs.

This argument implies that there is not much room for price policy to be effective in increasing the output rate, unless structural change takes place, to shift the short-run production function. At any rate, our production function for yield, Y_{ij}, is represented as

$$Y_{ij}(t) = f[X_{ij\ell}(t), Z_{ijk}(t)] \tag{1}$$

where i indexes regions, j crops, ℓ conventional inputs, k nonconventional inputs. In the production function, two groups of inputs are identified. One is the conventional inputs ($X_{ij\ell}$), which are basically supplied from the private sector, including the farm sector itself. The other is the nonconventional inputs (Z_{ijk}), which are structural change variables. Furthermore, two types of nonconventional inputs are distinguished. One is inputs which the public sector supplies the farm sector directly or indirectly through direct investment, subsidy, or loan programs. Examples include high-yield varieties, new cultivation practices, improved land, better institutions, and human capital. The other is the capital generated in the farm sector, which affects the yield level. An example of this type of input is perennial crops (fruit trees and mulberries in the KASM system); that is, tree-crop age composition and status of plant health. Tree-crop age composition is computed in FRESAL and plant health is internally computed in CHANGE, assuming that the status of plant health is dependent upon past input use.

In actual computation, we use the following projection equation:

$$Y_{ij}(t) = \left[1.0 + \sum_{\ell}\alpha_{ij\ell}(t)*\frac{\dot{X}_{ij\ell}(t)}{X_{ij\ell}(0)} + \sum_{k}\beta_{ijk}(t)*\frac{\dot{Z}_{ijk}(t)}{Z_{ijk}(0)}\right]*Y_{ij}(0) \qquad (2)$$

where $\dot{X}(t) = X(t) - X(0)$, $\dot{Z}(t) = Z(t) - Z(t) - Z(0)$, and α's and β's are appropriate elasticities. This form of equation can be derived from any form of production function by means of the Taylor expansion series.

Factor Demand Projection Subcomponent

In order to project individual crop yields, we must first project the levels of the conventional, as well as nonconventional, inputs used for individual crops. In this subsection we will discuss how the so-called "conventional input demand" is projected. The nonconventional input uses will be discussed in the following subsections.

Kinds of inputs considered were listed earlier as fertilizer, chemicals, other material inputs, and labor. What are the determinants of factor demand? We have seen that product and factor prices influence the production rate and, hence, supply. That is, farmer response to price is actually revealed in the level of factor use. Indeed, supply response is really a factor demand problem.

Input use intensity is also affected by technical relationships. In a dynamic process, such as the system presented here, these coefficients are changed over time. Structural change variables act as production function-shifters, as well as shifters of factor demand. To change these coefficients is a major purpose of a development plan.

In the model the individual factor demand function for each crop is constructed as a function of the economic and physical variables considered above, as shown in Figure 2. However, because of lack of appropriate time series data, we derive (conventional) factor demand functions from the production functions. Here we adopt the so-called "profit maximization assumption." The optimum input level--hence, output--derived under this assumption is often believed to be the upper bound of actual performance [17]. This implies that the model estimates are likely to be high, because all important constraints which farmers actually face are probably not considered in the model conceptualization. Thus, in order to make our projections more realistic, we impose several restraints in terms of finance, uncertainty, and resource fixity. These financial restrictions are that (1) total expenditure cannot exceed total supply of the capital budget; (2) credit used from all sources (own capital, credit from public institutions, credit from private moneylenders) cannot exceed the respective supplies; (3) the marginal rate of internal return to capital cannot be less than the appropriate interest rate; and (4) farmers' own capital may be disposed of in nonfarm uses, if desired, so that the marginal rate of internal return is equal to the salvage interest rate. To represent uncertainty and resource fixity restraints, factor demand elasticities with respect to prices are adjusted to reveal the direction, duration, and magnitude of price changes.

The resultant factor demand function derived from the profit function, constrained by production functions and conditions specified above, is represented in equation (3).

$$X_{ij\ell}(t) = \left[1 + \alpha_{ij\ell}(t)\frac{\dot{P}_{y_{ij}}(t)}{P_{y_{ij}}(0)} + \sum_n \beta_{ij\ell n}(t)\frac{\dot{P}_{x_{in}}(t)}{P_{x_{in}}(0)} + \gamma_{ij\ell}(t)\frac{\dot{\varepsilon}_i(t)}{\varepsilon_i(0)} \right.$$
$$\left. \sum_k \delta_{ij\ell k}(t)\frac{\dot{Z}_{ijk}(t)}{Z_{ijk}(0)}\right] * X_{ij\ell}(0) \qquad (3)$$

where $X_{ij\ell}$ stands for use of input (ℓ) for crop (j) in region (i); $P_{y_{ij}}$, for price of crop (j) in region (i); $P_{x_{in}}$, for factor price of input (n) in region (i); $\dot{P}$'s, $\dot{\varepsilon}$'s, and $\dot{Z}$'s are appropriate time derivatives; and α, β, γ, and δ are appropriate coefficients. Equation (3) is still a partial solution, since it contains at least one unknown variable, ε, besides the Z's. This variable is a Lagrangian multiplier plus one and is equivalent to the gross marginal rate of internal return to capital or, in this formulation, the marginal value product per unit of expenditure (MVPUE). We need to determine the value of this variable to project the so-called "conventional input levels," $X_{ij\ell}$.

By substituting individual factor demand functions for all crops into the overall budget constraint and solving it in terms of ε, we have

$$\varepsilon_i(t) = \frac{\varepsilon_i(0)}{\sum\sum\gamma_{ij\ell}(t)*X_{ij\ell}(0)} \left\{1 + \sum\sum\alpha_{ij\ell}(t)\frac{\dot{P}_{y_{ij}}(t)}{P_{y_{ij}}(0)} + \sum\sum\sum\beta_{ij\ell n}(t)\frac{\dot{P}_{x_{in}}(t)}{P_{x_{in}}(0)} + \sum\sum\sum\delta_{ij\ell k}(t)\frac{\dot{Z}_{ijk}(t)}{Z_{ijk}(0)}\right\} - \varepsilon_i(0) - \frac{\varepsilon_i(0)B_i(t)}{\sum\sum\gamma_{ij\ell}(t)*P_{x_{i\ell}}(t)*X_{ij\ell}(0)} \qquad (4)$$

where B is total supply of capital in the budget for region (i). Equation (4) can be interpreted as the demand function for the capital budget. Once $B_i(t)$ is given, we can project the factor input levels through equations (3) and (4). The first financial restraint listed above can be met through equation (4); however, there is yet no guarantee that specifications 2, 3, and 4 will hold. Let us see what we can do.

First of all, the capital budget, $B_i(t)$ is made up as follows:

$$B_i(t) = F_i(t) + G_i(t) + P1_i(t) + P2_i(t) \tag{5}$$

where F stands for farmers' own capital, G for government-supplied credit (short-term), and P1 and P2 for private moneylender credit, respectively, with low and high rates of interest. This means that the credit supply is a step function, as illustrated in Figure 3, where

$B1_i = F_i$, $B2_i = F_i + G_i$, $B3_i = F_i + G_i + P1_i$, and $B4_i = F_i + G_i + P1_i + P2_i$

We have not decided yet how much capital should be used. Should we use capital in the amount of B1, B2, B3, B4, or by some amount between B1 and B2 in Figure 3, for example? The guidelines for this decision are given in specifications 2, 3, and 4, stated above.

In order for these conditions to hold and for capital use to be determined, we play a game. That is, we start with B1 and compute the ε or MVPUE by equation (4) to see whether or not a farmer's own capital is fixed or whether the farmer needs to borrow more or to dispose of some of his own capital. This game is illustrated in Figure 3. If the ε turns out to be MVPUE1, he uses his own capital in the amount of D1 and disposes of the surplus (B1-D1), so that ε is equal to R1, which is the salvage interest rate plus one. If ε with B1 is equal to R1 or greater than R1 but less than R2--which is the government interest rate plus one--then his own capital is fixed by definition. This is a case illustrated by MVPUE2. Otherwise, he needs to examine whether or not to borrow money

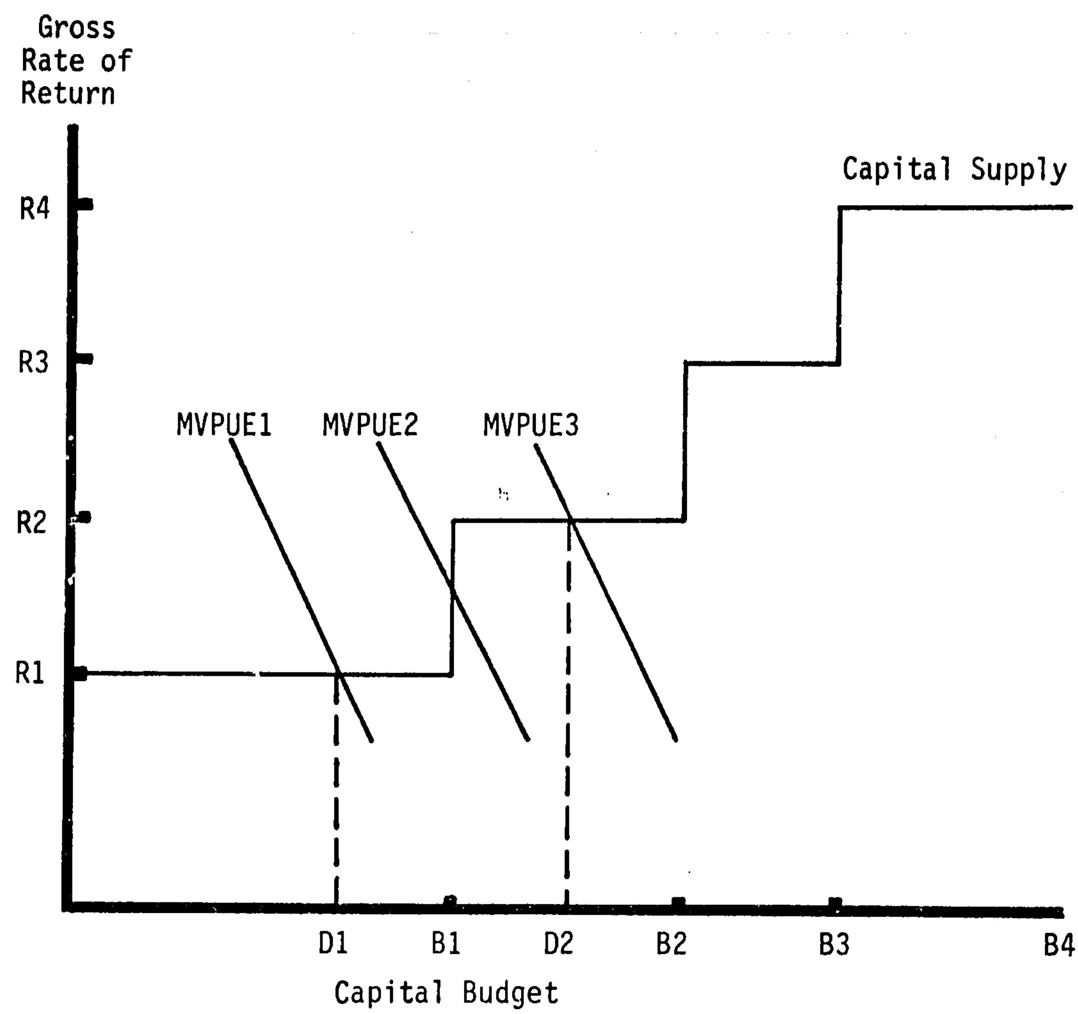

Figure 3. Demand Function for and Stepped Supplv Function of Capital Budget (for illustration)

from government-supported institutions, which are the chief credit-granting institutions. This game is continued until all four specifications hold. By playing this game, the amount of capital budget needed and the appropriate marginal rates of internal return to capital are simultaneously determined. Now we are ready to project individual factor input demands; but there is still an unexplained variable, Z, in equation (3).

Land and Water Development Subcomponent

Now we must explain how the so-called "structural change variables," Z's, which are supplied by the public sector, directly or indirectly, are determined. We distinguish two types of this variable: land quality change and biological technology change. The former is discussed in this section. The land quality change is a consequence of land and water development projects, the various types of which are listed in an earlier section. Kinds of farmland included in these land and water development projects are classified as follows:

1. Paddy administered under irrigation associations
2. Irrigated paddy
3. Partially irrigated paddy
4. Rain-fed paddy
5. Drained paddy
6. Consolidated paddy
7. Improved paddy
8. Developed tideland
9. Irrigated upland
10. Consolidated upland

11. Unirrigated upland
12. Developed upland
13. Improved pasturage
14. Unimproved pasturage

The kinds of farmland are not necessarily mutually exclusive. For example, irrigated paddyland could be drained or consolidated paddyland. Some possible kinds of land are not listed; for instance, undrained paddyland, unconsolidated paddy- or upland, etc. These are omitted here because we need only totals of paddy, upland, and pasturage and the proportions of improved land. We need to distinguish all these types of farmland because each yields a different impact in shifting production and factor demand functions. Also, each contributes differently to an increase in potential double-crop land.

In most cases, the reader will easily see the correspondence between the types of land listed above and the policy input variables stated earlier. However, some additional discussion is in order. First, the multipurpose, large-scale land development project is assumed to provide simultaneously irrigation, consolidation, and drainage for paddyland, as desired, and possibly tideland or upland development. Thus, such a project augments the productivity of improved land while transforming unimproved land to improved land or one kind of land to another.

Second, a large-scale irrigation project, like the multipurpose project, is sponsored by the central government and augments the paddyland-under-irrigation associations. The small-scale irrigation project is undertaken by a local government to augment the irrigated paddyland. In both cases, some idle land or upland located near the paddy will likely be transformed into paddyland during the process of project implementation. Third, a certain amount of farmland is transferred annually to other uses due to urbanization, industrialization, etc.

With this introduction, a simplified computation of mix of land types can be represented by

$$LAND_{ik}(t) = LAND_{ik}(0) + \int_0^t [A_{ik}(t) - \alpha_{ik} * T_i(t)]dt \qquad (6)$$

where A_{ik} is the rate of change in the land base in which the productivity is increased after improvement due to project (k) in region (i) in year (t), T_i is the rate of land transferred to other-than-farm uses in region (i) year (t), and α_{ik} is a parameter. In some cases, the potential productivity gain is obtained immediately after land improvement; in other cases, it is not. Examples in which delayed productivity increase occurs include tideland, developed upland, consolidation, etc. In cases of tideland, it takes more than five years after completion of the project for the potential productivity to be reached. This phenomenon can be modeled by either difference or differential equations, depending on assumptions made about the distribution of the time delay. Using a difference equation,

$$A_{ik}(t) = B_{ik}(t-T) \qquad (7)$$

where B stands for the rate of land just improved, but the potential productivity is not yet reached. T indicates the number of years required to reach the potential productivity gain.

There is also some time lag or delay between initiation and completion of a project. This land improvement time lag can also be modeled by either difference or differential equations. Using a differential equation, this can be represented as follows:

$$k\left(\frac{D}{k}\right)^{k} \frac{dB(t)}{dt} + k\left(\frac{D}{k}\right)^{k-1} \frac{d^{k-1}B(t)}{dt^{k-1}} + \ldots + k\left(\frac{D}{k}\right) \frac{dB(t)}{dt} + B(t) = E(t) \qquad (8)$$

where D is the expected average delay--number of years to complete a project; k is the parameter describing the shape of distribution of project completion time; and E is the rate of land scheduled for improvement (policy variables) in each year. Note that subscripts denoting regions and projects are omitted to avoid complication. It may be worthwhile to mention the property of this equation. When $k = 0$ in equation (8), $B(t) = E(t)$, which implies that land is instantaneously improved. When $k = 1$, equation (8) reduces to the first order differential equation, $D^{*dB(t)}/dt + B(t) = E(t)$, which means that the completion of projects implemented is exponentially distributed. As k increases, the time profile of the completion approaches the normal distribution; and if $k = \infty$, then equation (8) reduces to a difference equation like equation (7), $B(t) = E(t-D)$, which implies that the land is improved exactly D years after initiation, without exception.

For either equation system, there are several computer programs which will provide numerical solutions. Each program preserves the intermediate rate of land; that is land areas by development stage. This information is used (1) to compute the annual investment required for land and water development, with information on project costs required by development stages, and (2) to deal with the process of productivity growth on the newly developed land.

In summary, Z's in equations (1)-(4) are not measured in terms of absolute area, but in terms of proportion of improved land to appropriate total areas. As an example, suppose half of the total paddyland in a region is well drained. Then the Z value for the category becomes 0.5. This expression is necessary because we are concerned with the regional average yield, not with the total production of a crop. Now suppose the productivity difference between drained and undrained paddyland is one ton per hectare. Then the Z value of 0.5 implies that the average production function shifts up by one-half ton per hectare, as compared to that for undrained paddyland. When every piece of paddyland has been well drained, the function will have shifted up by one ton. (This numerical example is just an illustration.)

Biological Research Component

No one would deny that biological technology change is the most important, powerful measure in increasing farm production, especially in the Korean agricultural setting. Unfortunately, the progress and impact of biological technology modeled in this subcomponent are the most difficult phenomena to be mathematically and accurately represented or all the model subcomponents. Research and education are not purely stochastic phenomena, with chance occurrences relative to their initiations and outcomes. The probability of scientific discovery for a particular product, function, or service depends on the quantity and quality of resources allocated to it [6]. But the economics of biological technology changes remains as one of the least-developed areas in economics, both in theory and application [7]. Despite much work on the economics of biological research, the common conclusion reached seems to indicate that social returns to public investment are high!

Let us ask ourselves when a particular research outcome with a certain productivity gain would materialize if a certain level of research resources were allocated over time from a certain point in time. No one could answer exactly. Indeed, the new rice varieties, such as Tong-Il, Yoo-Shin, Mil-Yang Nos. 22 and 23 in Korea, and many other biological technologies are nothing but research outcomes which came about through public investment. While we know of such successful cases, we also know that many unsuccessful cases also exist. Social returns in this case are certainly nonpositive, although it is understood that scientific discovery involves a trial-and-error process. Instead, what we try to emphasize is that it is extremely risky to predict research outcomes in advance, in terms of the point in time at which they will materialize, the degree of productivity gains, and other biological properties.

For all this difficulty, we adopt a simplified assumption that during the planning horizon, a series of biological technologies, such as a new variety or cultivation practice, will be materialized without exception at certain points in time, with certain levels of productivity gains for all crops under consideration at the experiment station. This is illustrated in Figure 4.

This assumption may or may not hold, depending on research investment allocated and other variables involved. We treat the assumption made in Figure 4 as a basis for the sensitivity analysis. This will provide information on the consequences of alternative assumptions

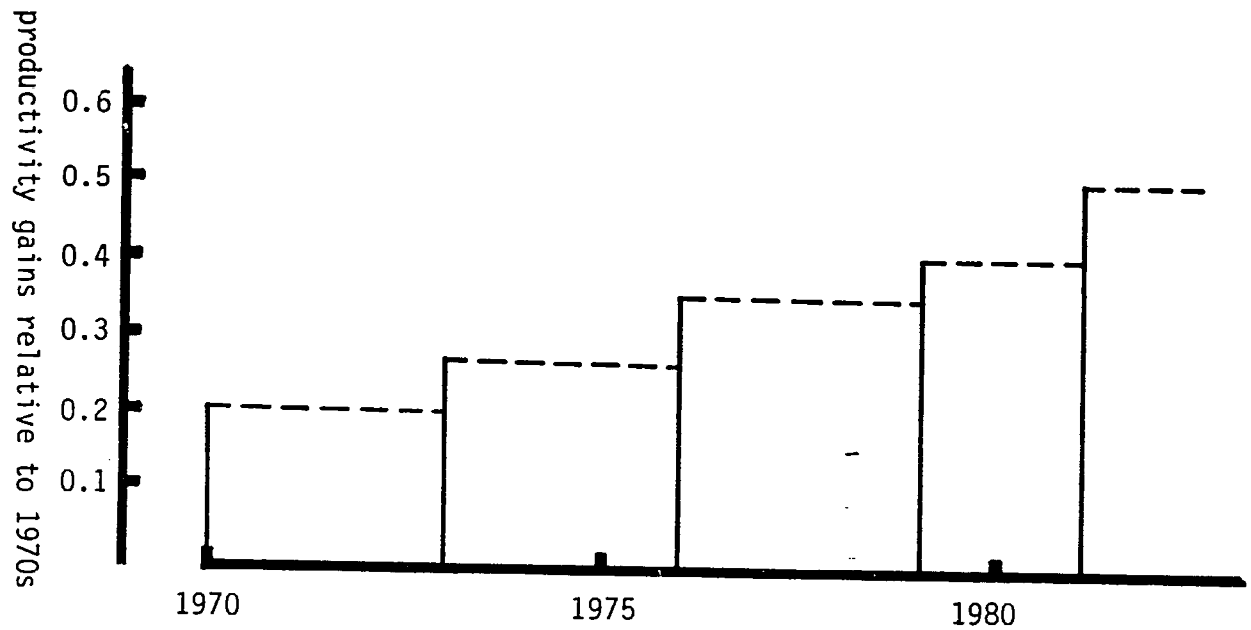

Figure 4. Hypothetical Illustration of the Points of Time New Varieties Appeared and Their Productivity Gains Relative to 1970's for a Crop at Experiment Station

about biological technology development on the performance of the farm sector.

Through this sensitivity analysis, we obtain information on the desired rate of biological technology change needed for achieving certain policy goals. In turn, this information can be used in designing and directing research programs. Suppose we have tentatively concluded that it is desirable to develop a series of new varieties that would increase productivity of a crop by 50 per cent, say, by 1985. Then technical feasibility will be examined. If it is feasible, then an investment will be made. If it is concluded not to be feasible, then several alternative policies can be examined: (1) the possibility of developing new varieties of other substitute crops, (2) the possibility of obtaining the same goals by investing more for land and water development or others, and (3) the economic feasibility of importing food through international trade by expanding export industries, etc.

Innovation Diffusion Subcomponent

After accepting the assumption made in Figure 4, we turn to modeling the process of adopting the technology made available. The new rice variety named Tong-Il, having about a 30-per-cent productivity gain, appeared at the experiment station in 1970. Dissemination was started on this variety in 1971. Despite an intensive government program, total paddy area in which this variety was adopted was only about 40 per cent by 1975. What would be the implication of this fact? Why do all farmers not adopt this variety on every piece of paddy? Basically, there are two reasons: imperfect knowledge, involving uncertainty, and insufficient area for which the new technology can be advantageously adopted. In connection with these reasons, several points must be considered: (1) the potential maximum area of farmland to which a new technology could be advantageously disseminated, (2) the speed of adoption, (3) factors accelerating the diffusion rate, and (4) actual (average) productivity gain at the farm level.

Before explaining the subcomponent structure, several remarks are in order. Both subcomponents, land and water development and innovation diffusion, are modeled basically by a differential equation system. Nevertheless, they are very different systems in many respects--the former is a physical process, whereas the latter is a social process. Thus, the latter requires equations and parameters describing farmer behavior. Sometimes their behavior is not exactly known. In this sense, this subcomponent modeled in CHANGE may be difficult to structure and parameterize.

In the case of the land and water development subcomponent, we implicitly assumed that production factors (land quality) supplied from the public sector are instantaneously demanded by farmers; that is, supply is always equal to demand. On the contrary, this assumption cannot be applied for modeling the diffusion process. Farmers do not necessarily instantaneously adopt a new technology that is supplied, due to the uncertainty involved. This is a disequilibrium system in the short run. However, we adopt Cochrane's "treadmill" hypothesis [3] in the long-run context, insisting that average farmers eventually will adopt a new technology that is made available.

Potential Maximum Area to Which a New Technology Can Be Adopted

A new technology should be better than the old in terms of the yield level, lower production cost, or some other production-improving characteristic. However, there is no guarantee that this new technology contributes to, say, a higher yield in all cases. That is, it may be better only for certain locations, weather conditions, farmers, and farmland which have particular characteristics. For a given new technology, the potential area can be extended by training farmers, improving farmland, and so on. Despite this, we assume, until more information is available, that the maximum potential suitable area is constant for each technology (k) shown at different points of time for each crop (j) in each region (i).

The Process of Technology Diffusion

When will adoption of each new technology be completed? Or how long will it take to complete adoption? It is known that the adoption curve or diffusion rate distribution has a bell-like shape and approaches a normal distribution. This process can be modeled with a higher-order differential equation, such as equation (8), indicated above in a previous section. Then, in this case, B(t) will be areas to which a new technology is completely adopted in year t. D will be the expected average year of adoption. The shape of the distribution is again characterized by k. Finally, E(t) stands for areas scheduled for the adoption in year t.

In the process of diffusion, we adopt Campbell's "adoption tree" hypothesis [2] which implies that (1) trial does not necessarily mean adoption, (2) it may take more than one year to completely decide to adopt, and (3) one may try it several times before adoption. Rejection after trial is called the dropout rate. This rate, the expected average delay, and the rate of land area entering the adoption process are assumed to be some function of public investment (budget for extension), the degree of regional specialization, profitability, and the importance of a crop in a region.

Productivity Gain at the Farm Level

Once the rate of adoption in each year is determined, we are ready to compute both the accumulated area by integration and the regional average productivity gain, since we know the area adopted and productivity gain expected. We may well assume that (1) the resource base and and goals of farming on the average farm are different from those on the experiment station and (2) farms with a good resource base or equipped with better knowledge would adopt a new technology first. This argument then implies that (1) actual average productivity gain at the farm level is likely to be less than on the experiment plots; and (2) as a new technology is disseminated over farms, the productivity gain on individual farms would decline [4]. That is, the regional average productivity gain due to a new technology is treated as a decreasing function of accumulated land area to which that new technology is adopted, with an intercept that is smaller than the productivity gain at the experiment station.

Innovation Made Available from the Nonpublic Sector

It is obvious that some farmers act more or less as innovators in selecting seeds, using production factors, or applying husbandry suitable to their specific farm or farm location. Other farmers imitate the progressive farmers. On the other hand, the agribusiness firm that supplies the farm sector with modern inputs or processes farm products engages in research and development and also disseminates findings to farmers. It is assumed that (1) all this indigenous innovation occurs continuously and (2) the rate of diffusion of this innovation is an increasing function of public investment.

Summary of the Model Structure

Going back to equation (2), the structural change variables, Z's, other than the ones internally computed, are determined in each year through the mechanisms specified in the last three sections. The levels of these variables basically depend on the levels of policy input variables. These Z's are in turn fed into equation (4) with other policy variables, such as credit and supported prices, to determine the marginal rate of internal return to capital, ε. Then this rate, ε, and again, the Z's and the supported prices are fed into equation (3) to determine the so-called conventional "input demand levels" in each year. By this process all production factors specified in equation (2) are projected. Thus, individual crop yield levels can then be projected.

Data Requirements and Parameter Estimations

The structural relationships and their parameters will determine jointly the behavior of a system model. We have seen in the previous section that CHANGE is a most complicated and heterogeneous system. This fact induces us to require many different kinds of data from diverse sources and varying estimation techniques. Three kinds of data are required: parameters, exogenous variables, and initial conditions.

Parameters

Basically, the parameters to be estimated are of three types: behavioral, physical, and accounting. The most critical parameters which seem to dominate the behavior of CHANGE, as well as the whole system of KASM, are first, physical production relationships. These include productivities of the so-called "conventional inputs," and the degree to which the "nonconventional structural factors" shift the short-run production and factor demand functions. The former is indirectly estimated, mainly because of data problems. Individual factor shares are used as proxies of their respective productivity elasticities. For the latter, data come from many sources: case studies, experiments, etc. The parameters used for these productivity coefficients are, in a sense, synthesized. Essentially the same sort of technique is used for estimating factor demand elasticities with respect to structural change variables.

The second group of crucial parameters are the behavioral parameters which relate price and financial variables to factor demands. Again, these variables are indirectly estimated because of the same data difficulties. These parameters are really derived from the production function, as stated in the text.

There are other types of behavioral paramters. These are related to farmers' behavior in adopting new technologies. Since the farmers' behavior on this subject matter is not well understood and no data previously collected are available, once again we had to use tentative data, inferred from the real world. However, while individual subcomponent models were built and tested, these parameters were more-or-less justified.

We have still other types of physical data, most of which are essentially engineering data related to land and water development projects. The basic set of these data was supplied from the Agricultural Development Corporation (ADC) and was based on engineering field surveys and experiments. The ADC uses this data set for making policy recommendations and for developing implementation plans for land and water development projects. The kinds of data included are (1) completion time of a project, (2) the shape of the completion time distribution, (3) unit costs of project implementation, (4) productivity growth on newly improved or developed land, (5) time required for productivity maturity, (6) investment required by land development states, and many others.

Exogenous Variables

We discussed the policy variable inputs earlier. These are, of course, exogenous variables to CHANGE and KASM. There are still other types which are exogenous to either CHANGE, exclusive of KASM, or to KASM. The former includes tree-crop age cohorts, the degree of regional specialization, etc., which are computed directly or indirectly from endogenous variables computed in other KASM components. Those exogenous to KASM include (1) the maximum potential farmland area needing improvement by various land and water development projects and (2) development costs. Information on these variables was also supplied by ADC. Another group of inputs exogenous to KASM is information on farmers' own capital and noninstitutional private loans made available for agriculture. Again, because of a data problem, primitive assumptions were made on the value of those variables.

Initial Conditions

Since CHANGE is a dynamic model, the initial conditions play an important role in determining the system behavior. Because CHANGE is a heterogeneous system, diverse initial conditions are also required. These include various classes of land, yield levels by crops, factor input levels by crops, prices by crops or production factors, tree-crop age composition, and many others. Basically, appropriate statistics in 1970 (base year) appearing in the official government publications are used. However, some data are not available in official statistics. A typical example is factor uses, especially for crops other than rice, barley, and wheat. Thus, in many cases, information synthesized from many different case studies is used.

In sum, since CHANGE is quite sophisticated, synthesized, and complicated, there is no way to estimate all parameters simultaneously. This is true even for the production function for a crop in a region. Thus, the method and techniques used to estimate separately each of the parameters shown varied widely from simultaneous estimation of subsets of data to guesstimates.

Component Model Testing

CHANGE has been extensively tested while being developed and in the process of sensitivity analysis and policy experiment runs. The philosophical base of the model testing has rested much on an objectivity or credibility test (see Chapter 1 and also [11]). Because of the nature of the system modeled, historical verification alone is impractical.

First, checks were made to determine whether or not variables had correct signs, behaved appropriately, and remained within known bounds. In addition to this, while conducting sensitivity tests, including policy experimental runs, we found that not all the relevant variables responded appropriately to changes in parameters or policy input levels. Whenever inappropriate responses were detected, a relevant part of the system model was corrected. This process was repeated until the model worked reasonably well. This type of procedure was first used for testing individual subcomponent models of CHANGE and second for testing the whole CHANGE model together after individual subcomponent models were linked.

Finally, some of the major model outputs were contrasted against historical data. In these runs, values of policy inputs and other exogenous variables were used which actually prevailed in the real world. However, some statistical data were unavailable or published incorrectly and inconsistently. Differences between actual or historical and projected values should be interpreted as reflecting random error due to weather conditions and errors due to incorrect input data, in addition to possible misspecification of the model structure. An example comparison for rice yield is shown in Figure 5. It should be kept in mind when interpreting the projection made beyond 1975 that the projected value is exclusively the function of assumed policy input levels.

Historical tracking prior to the base year, 1970, may be desirable for at least the key major output variables. On the other hand, model behavior during the period representing the low-level, stationary equilibrium state of Korean agriculture may not be used as evidence for a dynamic agriculture, where structural transformation takes place. Structural transformation in agriculture has only been a serious goal in Korea since the Third Five-Year Plan, 1972-76. For these reasons, in addition to constraints we have on resources, we did not try such historical tracking.

Finally, Table 1 shows the sources of yield increase for rice as an example. The table corresponds to the yield levels in Figure 5. Biological technology appears to be the most powerful engine for productivity growth. Thus, we may conclude that whether or not the yield level increases over time sufficiently to achieve development goals depends on the rate of biological technological change, especially for a country where the man/land ratio is high.

However, we should keep several points in mind when drawing this conclusion. Improvements in land and people are neither substitute nor supplementary, but economic complements with biological innovation in the dynamic process of development. It should also be realized that supply availabilities of the so-called "conventional inputs" are necessary to

Table 1. Sources of Yield Productivity Growth Rate (in percentages) Relative to the 1970s, Rice on the Average as an Example, Based on Sample Run

Year	Due to Change In				
	Conventional Input Uses	Land and Water Development[1]	Research and Extensions[2]	New Land[3]	Total
1971	0.6	0.2	0.7	---	1.5
1972	0.4	0.3	2.0	---	2.7
1973	1.0	0.4	3.5	-0.1	4.8
1974	1.5	0.6	5.8	-0.1	7.8
1975	2.6	0.8	9.1	-0.1	12.4
1976	3.2	1.1	11.4	-0.1	15.6
1977	3.7	1.5	14.3	---	19.5
1978	4.7	1.9	17.5	0.4	24.5
1979	4.8	2.8	21.1	0.6	29.3
1980	5.3	3.8	27.1	0.4	36.6
1981	5.6	4.6	31.6	0.6	42.4
1982	5.9	5.0	35.5	-0.9	45.5
1983	6.1	5.0	38.3	-2.1	47.3
1984	6.2	5.0	41.1	-3.0	49.3
1985	6.9	5.0	45.[illegible]	-3.4	53.8

[1] This source brings about three different impacts on the average yield: first, it may increase it (irrigation, drainage, and low-productive paddy improvements); second, it may decrease it (tideland development); and third, it may have neutral impact (paddy consolidation). The figures in this column are averages of these three forces. Thus, it is not appropriate to evaluate land and water development projects in terms of average productivity only.

[2] Sum of biological technological changes made available by both public and private sectors.

[3] Productivity change due to change in land in the stage of productivity growth. Remember that (1) for consolidation, for example, the yield level decreases in the first year after project completion and then starts to grow toward the normal yield; but (2) for drainage or low-productive paddy improvement, the yield level starts to grow from the first year toward a higher level than the normal yield.

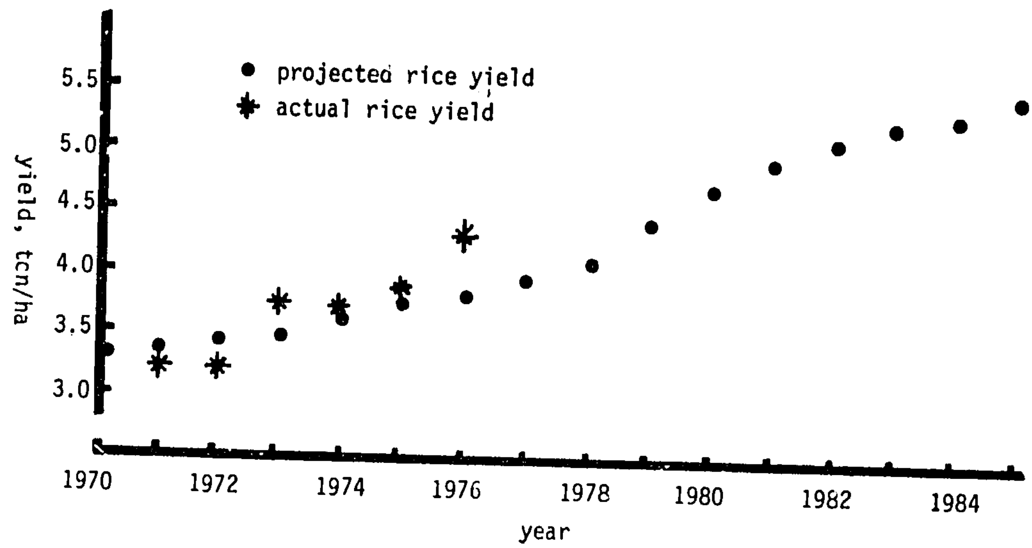

Figure 5. Projected and Actual Yields for Rice, as an Example, Based on Sample Run

support this innovation for it to be effective. One should notice that a positive price policy and finance program would be more effective in this dynamic process than in the static equilibrium state and would become a complement to, not a substitute for, biological innovation.

This conclusion is rather general. Our critical concern then becomes whether it is possible to invent a series of, for example, new seeds for a desired crop, so that development goals can be achieved. From the beginning, we emphasized a comprehensive and consistent sector planning activity. One of the most important responsibilities of the model-builder, after a comprehensive model is constructed, is to design the development strategy which meets consistency and optimality criteria.

Now let us be more specific. Would continuation of the present food consumption pattern of rice be consistent with the production possibility of rice in Korea in the future when more population, greater per capita income, and less farmland and labor are expected? Is the breeding for the small grains, such as rice, comparatively easier than that for other grains? Research activity is rather a risky enterprise. It is known that it is much easier to breed for a crop which has roots, leaves, or stems that are used for food or feed--such as potatoes, vegetables, forages, etc. Then the question is, Which kinds of crops are easier to breed within the Korean agricultural setting and, at the same time, meet other consistency and optimality criteria?

Since feed grains will become relatively more important and livestock products are substitutes for food grains in consumption as well, we chose potatoes as an alternative to rice or other small food grains in the breeding program and demonstrated in another paper [14] that this program would be more likely to contribute to meeting total grains (food as well as feed) desired or even an improved diet.

Further Model Improvement Needs

In an earlier section, we noticed that CHANGE requires tremendous amounts of data from diverse sources in order to estimate desired parameters or other variables. The data base of CHANGE presently used is rather poor. The first priority for further model improvement should be given to data base improvement. In fact, data-updating should be continued as new and better sources become available. The same is also true for updating the model structure for the model to remain useful for an ever-changing system.

In addition, several segments of the model structure should be more fully understood. We have included several simple behavioral relationships in the model, such as innovation of new technologies, the farm consumption-saving-investment relationship, the noninstitutional private money market structure, and the real price behavior--including interest rates, etc. This is only a partial list.

Several other policy or environmental variables might affect major output variables of CHANGE. Examples include improvement in transportation and market systems, rural electrification or other infrastructure, and change in farm size and in migration patterns. The effects of these variables on agricultural production, as well as on rural development, should be better understood.

The so-called "conventional production factors" are now mainly recognized as an economic complement to the nonconventional inputs in the process of agricultural development. The energy crisis, as we all know, has had a great impact on the input supply sector in terms of supply prices, quantity, and even quality supplied. On the other hand, the agricultural market system in Korea is relatively primitive, and its value added shares a relatively small portion of the total value of food supplies. However, it is expected that the role of the market, especially the processing subsector, will become more important as economic development proceeds. In other words, the roles and functions of input supply and product processing subsectors may need to be understood in relation to farm production, production rates, and overall rural development.

In conclusion, it appears that any kind of problem-solving model obviously faces a data problem, as does CHANGE. The data set presently used for CHANGE is essentially a similar set of data used when the public decision-maker produces a practical plan or when a pencil-and-paper projection is made by using some sort of informal model. The essence of CHANGE is, again, basically very similar to the traditional informal methods in terms of methodology used. But CHANGE contains more economic and behavioral relationships and intends to reflect more of what is happening in the real world. Despite the inadequate data set used, CHANGE appears to be more efficient and better able to provide a sound basis for development planning and policy analysis than the more informal methods previously used.

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CHAPTER 11

THE RESOURCE ALLOCATION AND PRODUCTION COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

Hartwig de Haen
Friedrich Bauersachs

Problems and Policy Issues to be Analyzed

During the last 15 years, the Korean agricultural production system has experienced drastic changes with respect to kinds, levels, and composition of resources used and resource productivities, as well as levels and composition of output. This may indicate that Korean farms have continued their transition from traditional subsistence production to a commercialized market orientation. Considering the various interactions between agriculture and the rest of the economy, it seems safe to state that this structural change was both cause and result of a considerable national economic growth. In fact, the underlying hypothesis, on which current economic policies as well as modeling and planning efforts in Korea are based, is that an intensive reallocation of resources within agriculture and changes in the production structure will continue in the future in spite of the remarkable change that has already taken place in the past. Any planning and policy analysis will have to take this into account.

Table 1 provides some empirical information on the dynamics of resource use and production in the past. Although the growth rate of

Table 1. Selected Indicators of Korea's Resource Use and Production, 1960-1974

	Period			Average Yearly Growth Rates (Percentage)	
	1/1960 2/1961 3/1962 4/1963	1967	1974	(1960, 1961, 1962)-1967	1967-1974
Total Population (millions)	24.99 1/	29.54	33.46	2.4	1.8
Farm Population (millions)	14.56 1/	16.08	13.46	1.4	-2.5
Share of Farm Population (%)	58.0 1/	54.40	40.0	-0.9	-4.3
Share of Agricultural GNP (%)	43.5 3/	37.8	24.9	-2.8	-5.9
GNP Growth Rate Agr./Economy	-5.8/3.1	-5.0/7.8	5.7/8.6	---	---
Area of Cultivated Land (millions of ha)	2.03 1/	2.31	2.24	1.8	-0.5
Fertilizer Use (thousands of MT)	308.5 2/	486.5	836.7	5.6	8.1
(MT/ha)	0.15 2/	0.21	0.37	5.6	8.1
Number of Tillers (thousands)	30.0 2/	3,819.0	60,056.0	80.8	39.4
Total Food Grain Production (millions of MT)	5.3 1/	6.8	7.3	3.7	0.9
Vegetable Production (millions of MT)	1.2 1/	1.9	3.0	6.9	6.7
Cocoon Production (thousands of MT)	---	10,903.0	30,980.0	16.9	17.4
Korean Cattle (thousands of hd)	1,010.0 1/	1,243.0	1,778.0	3.0	5.1
Dairy Cattle (thousands of hd)	.8 1/	10.4	73.2	35.5	27.9
Hogs (thousands of hd)	1,397.0 1/	1,296.0	1,818.0	-1.1	4.8
Value of Agricultural Imports/ Exports Ratio	2.67 4/	1.98	2.63	---	---
Yields (MT/ha)	1957 to 1960	1964 to 1967	1971 to 1974	1957/1960 to 1964/1967	1964/1967 to 1971/1974
Total Food Grain	1.91	2.28	2.66	2.5	2.2
Paddy Rice	2.78	3.11	3.50	1.6	1.7
Barley and Wheat	1.56	1.87	2.16	2.6	2.0
Sweet Potatoes	13.70	17.50	17.60	3.5	---
Soybeans	0.52	0.59	0.87	1.8	5.5
Chinese Cabbage	---	12.60	12.70	---	---

Sources: Yearbooks of Agriculture and Forestry Statistics, Seoul, 1971 and 1975.
Major Statistics of Korean Economy 1975, EPB, Seoul, 1975.

agricultural GNP is still lagging behind the total economic growth rate, the ratio between the two growth rates is rising and has doubled during the last ten years. (Between 1972 and 1975 the growth rate of agricultural GNP was 4.9 per cent, as compared to 9.4 per cent of the total economy average, and the agricultural share of the GNP of the total economy steadily declined from 28 to 24 per cent.) This was possible in spite of the fact that during the second half of the 14-year period between 1960 and 1974, agricultural labor and land resources have been declining in absolute terms; whereas both had still been growing before. Some of this resource withdrawal has been offset by increased fertilizer application and mechanization. However, the growth of production was still not high enough to meet the growing demand. The figures in Table 1 indicate that the import-export deficit for agricultural commodities has been widening in relative and in absolute terms. Moreover, in spite of rice yield increases and price support policies, the growth rate of food grain production has declined below the population growth rate. Also, there is an increasing requirement for concentrates to feed the rapidly growing livestock herd. The slow rate of grain production increase may partially be due to a rise in areas of nongrain commodities; e.g., vegetables. However, other important reasons may include the decreasing cultivated area, a reduced labor force, and, possibly, changes in age and sex structure of the labor force.

It is expected that the farm population will decline further to about 11.5 to 12 million in 1985 and that the cultivated area will be reduced for urban and industrial use by another 0.2 million hectares (10 per cent) by 1985. Hence, a rise in agricultural production, stated as the most important goal of agricultural policy, will require a continuation of this process of structural change. Taking into account a continuation of national income growth and an increasing food demand, policies aiming at higher food self-sufficiency, on the one side, or world market scarcities, on the other side, might even increase the pressure on agriculture to reallocate resources and to increase the adoption rate of technical change.

Moreover, income elasticities for various food items indicate a rising proportion of protein in the diet or, more generally stated, of livestock in the overall production structure. Especially dairy and beef production will most likely continue to expand more than proportionally and, hence, require pasture land development and intensification, feed grain import, and capital investment in herd expansion and buildings. Increasing livestock production will mean more competition between food and feed grain producton. It may also accelerate the rate of mechanization by further replacing dual-purpose draft cattle by more specialized beef cattle. This list of examples for adjustment and structural change in resource allocation and production could be easily extended to other areas, such as irrigation and water development, to enable fertilizer intensification and rising double-cropping ratios, etc. However, it will suffice to indicate the importance of analyzing this process by means of a model component that is both sufficiently detailed and dynamic.

Some of the basic questions which the farm resource allocation and production component (FRESAL) is designed to approach can be summarized as follows:

a. Explanation and Basic Projection

Given initial resource endowments, production patterns, projected rates of change of land and labor inputs, technology sets, and historical prices, how will farmers allocate their productive resources to various enterprises and how will they finance production and investment? What will be their supply responses?

b. Sensitivity Analysis of Exogenous Factors

How would alternative assumptions with respect to exogenous variables and key model parameters--e.g., alternative off-farm migration rates, rates of technical change, or wage-interest ratios--affect the expected level and time profile of technology, input use, production, and farm income?

c. Policy Analysis

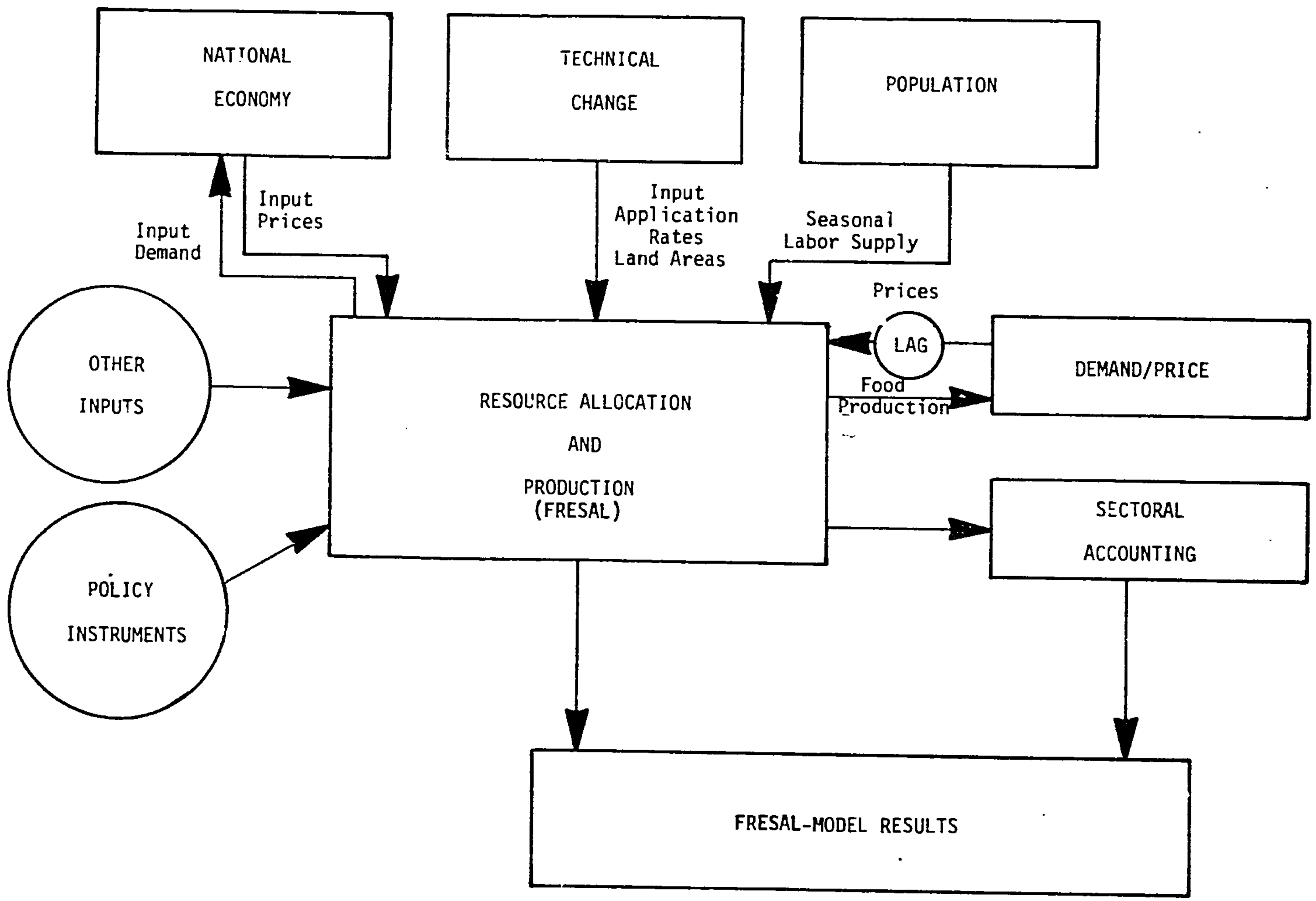
What will be the impact of alternative agricultural policies, namely price policies, import quotas, or input subsidies, on the performance indicators mentioned before?

Modeling Farm Resource Allocation within an Interdependent System: Boundaries of the Component

Basically, FRESAL is designed to model the activities of the farm households as behavioral decision units. This provides a general definition of component boundaries to the environment, the latter being represented by the factor and product market. The population dynamics result from demographic characteristics and off-farm employment opportunities and by policy measures and exogenous factors affecting resource endowment and resource productivities, as well as institutional considerations. The mainstreams of component interaction within the overall model have been demonstrated in earlier chapters.

Figure 1 indicates the major linkages of FRESAL with the rest of KASM, including policy inputs, exogenous variables, and component-specific output variables. Seasonal labor supply, producer prices,[1]

Figure 1. Major Linkages between the Resource Allocation Component and the Rest of the Korean Agricultural Sector Model



and yield levels, with the corresponding input application rates, are major inputs into FRESAL from other KASM components. Other inputs (exogenous) are land, by three different categories; prices of variable inputs; interest and wage rates; technical coefficients with respect to mechanization and labor use; double-cropping ratios; etc. Policy inputs include input price subsidies, credit, and land development. Outputs to other KASM components are food production levels by commodity, agricultural farm income, and feed grain imports. Other outputs include input use, technology levels, shadow prices of fixed resources, capital stock, savings, and indebtedness.

Internal Structure of FRESAL

Basically, farmer resource allocation decisions are modeled in a sequence of linear programming models dynamically linked with the overall KASM. This component KASM can be described as block recursive, with one block containing a set of inequalities and a selection rule (objective function) representing a behavioral assumption as to how farmers choose among alternative actions in any given period. This is an attempt to represent the adaptive behavior of the system as a function of two equally important feedback mechanisms: internal feedback within the farmers' decision framework and external feedback from markets, demographic conditions, and policy reactions. Figure 2 contains the internal structure of the component. Basically, it consists of an allocation subcomponent and a production and accounting subcomponent. The allocation subcomponent contains a one-period linear programming model allocating given resources to production, investment, and financing activities; an

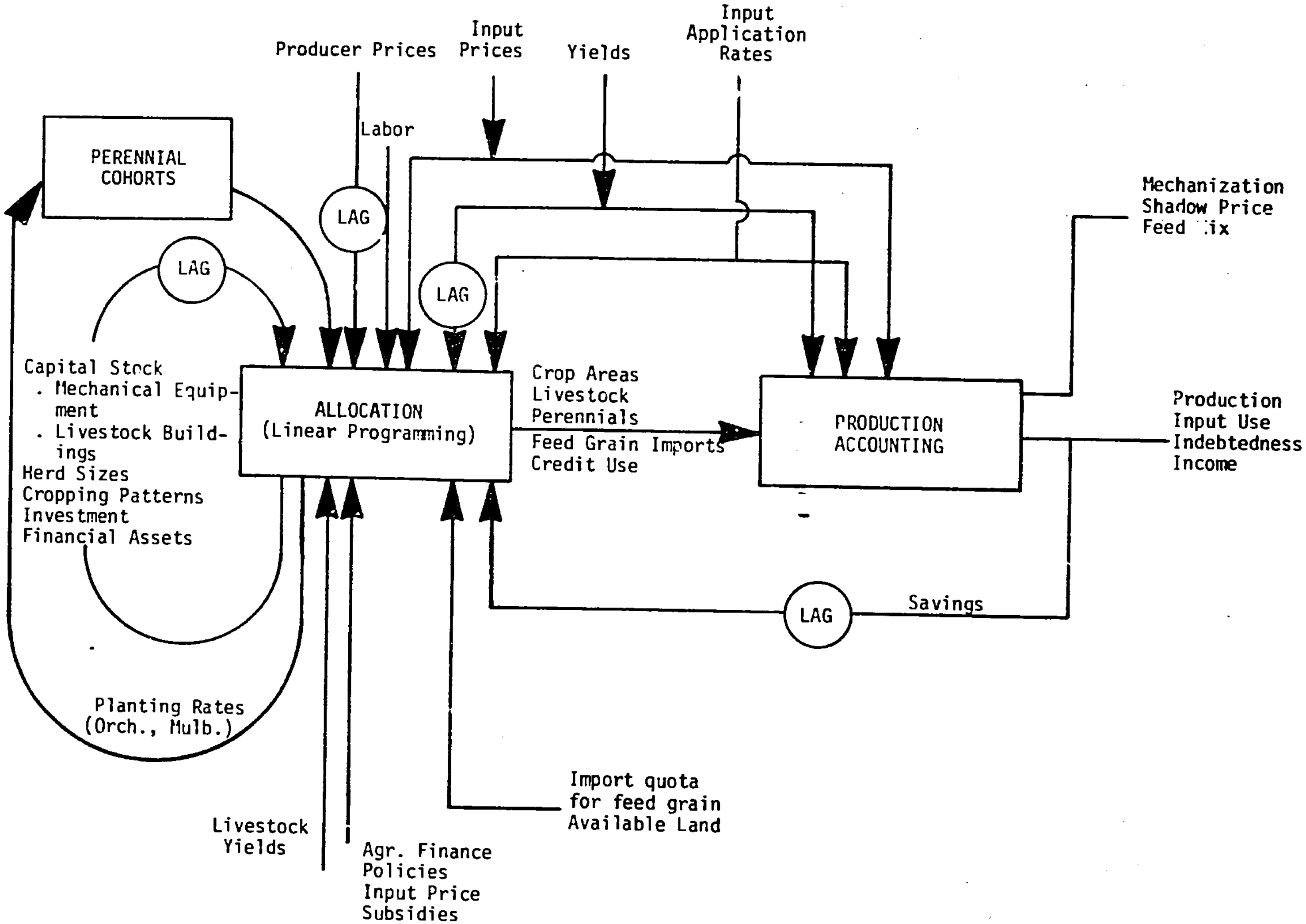


Figure 2. Internal Structure of the Resource Allocation and Production Component

internal feedback relating previous actions to current decisions; and an external feedback establishing the interactions with the other components. The production and accounting subcomponent aggregates the detailed programming results and computes production levels for the 12 crop and the five livestock commodities. Moreover, this subcomponent computes other variables resulting from resource allocation and production; namely, income and savings and input requirements, such as fertilizer, fuel, chemicals, feed grain, etc. Following is a more detailed description of the resource allocation subcomponent, divided into (a) the allocation of resources in any given period and (b) the dynamic feedback linking the periodic decisions.

Resource Allocation

A farm in Korea is typically small and multienterprise, producing annual crops on paddy- and upland, perennials, and, to a growing extent, livestock products. Since the cultivated cropland is essentially limited to three hectares per farm, livestock production provides a major source for additions to the income capacity of the farms. The multienterprise character of the Korean farms and the effectiveness of various common constraints at the farm level make it difficult to model resource allocation separately for individual commodities. Moreover, the expected further technical progress and changes in consumer preferences do not allow any kind of simple trend extrapolations. Finally, trend extrapolations or other exogenous projections could not easily enable any analysis of policies leading to structural change within the sector, since they rarely account for substitution processes. Because of these considerations the decision was made to model farmer decision processes with respect to allocation and production explicitly. The assumed decision rule, supported by various case studies, may be defined as "cautious optimizing." According to this rule, farmers try to maximize expected profits subject to technical, institutional, and behavioral restrictions, provided that the possibility of ruin (income less than subsistence level), is negligibly small. The allocation decisions resulting from this rule are subject to change in any new period, depending on any deviations between expectations and realizations affected by the environment. Mathematically, the allocation decisions are simulated by a recursive linear programming model,[2] which, for any given period, has the following form:

$$\pi_t^* = \max_{x_t} \overline{Z}_t \cdot \overline{X}_t$$

such that $\underline{A}_t \overline{X}_t \leq \overline{Y}_t$

$$\overline{X}_t \geq 0$$

where π^* is the expected "optimal" (or rather, "satisfying") value of the objective function; $\overline{X}$ is the vector of activity levels, $\overline{Z}$ is the vector of expected returns per activity unit; $\underline{A}$ is the matrix of technical coefficients; $\overline{Y}$ is the vector of physical, behavioral, or institutional constraints.

The dynamic internal and external feedback is established through three sets of linkage functions; namely, an objective function, a constraint vector, and input-output matrix operators:

$$\bar{z}_t = z\left(\vec{x}^*_{t-1}, \ldots, \vec{x}^*_{t-p}; \vec{r}^*_{t-1}, \ldots, \vec{r}^*_{t-p}; \bar{u}_{t-1}, \ldots, \bar{u}_{t-p}; \bar{v}_t\right)$$

$$\bar{y}_t = y\left(\bar{y}_0; \vec{x}^*_{t-1}, \ldots, \vec{x}^*_{t-p}; \vec{r}^*_{t-1}, \ldots, \vec{r}^*_{t-p}, \bar{u}_{t-1}, \ldots, \bar{u}_{t-p}; \bar{v}_t\right)$$

$$\underline{A}_t = A\left(\vec{x}^*_{t-1}, \ldots, \vec{x}^*_{t-p}; \vec{r}^*_{t-1}, \ldots, \vec{r}^*_{t-p}; \bar{u}_{t-1}, \ldots, \bar{u}_{t-p}; \bar{v}_t\right)$$

where* indicates optimality; $\bar{r}$ is the vector of dual values (shadow prices of constraints); $\bar{u}$ is the vector of KASM output variables--i.e., variables that are exogenous to FRESAL but endogenous to other components; and $\bar{v}$ is the vector of exogenous variables.

The matrix A is basically block diagonal, with one block for each region and additional national constraints:

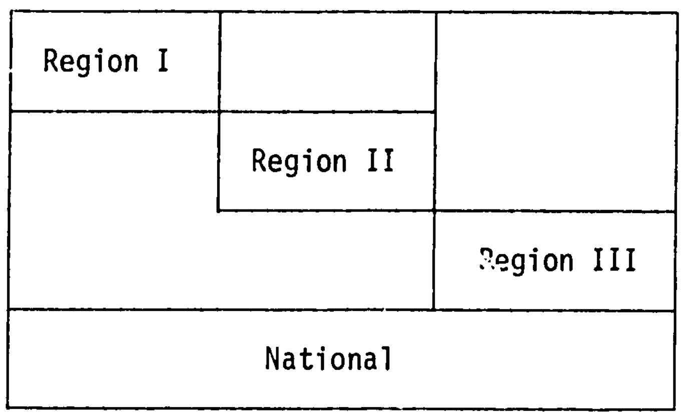


Figure 3. Regional Disaggregation of the Coefficient Matrix in FRESAL

The current version of the model is not using the potential for the regional breakdown, mainly in order to increase the computational efficiency, but also due to a lack of sufficiently accurate regional data. The main structure of the yearly allocation model on the national level[3] is sketched in Figure 4.

Figure 4. Activities and Constraints of FRESAL

Constraints		Annual Crop Production: Traditional	Annual Crop Production: Modern	Roughage Production: Traditional	Roughage Production: Modern	Animal Production: Cattle (Draft, Dairy Beef)	Animal Production: Hogs/ Poultry	Perennials: Planting	Perennials: Production	Investment and Financing: Bank Account	Investment and Financing: Investment	Investment and Financing: Loans	Admissable Loss	Internal Transfers: Paddy to Upland	Internal Transfers: Feed or Sale	Internal Transfers: Alternative Labor Use	Imports
Land	Paddy, Summer Upland, Winter Upland	X	X	X	X			X						X			
	Pasture			X	X												
	Perennials								X								
Labor	Human Labor (by seasons)	X	X	X	X	X	X	X	X								
	Draft Cattle (by seasons)	X		X		X					X					X	
	Machinery (by seasons)		X		X												
Capital	Liquid Assets: Total (savings, working cap.)	X	X	X	X	X	X	X	X	X	X	X					X
	Liquid Assets: Investment cap.										X	X					
	Farm Capital in Buildings and Livestock					X	X				X						
	Internal Credit Rationing	X	X	X	X	X	X	X	X	X	X	X					
Risk and Behavioral Constraints	Minimum Income	X	X	X	X	X	X	X	X	X							
	Risk Constraint	X	X										X				
	Flexibility of Production and Herd Expansion	X	X	X	X	X	X	X		X			X				
	Adoption of Technology							X									
Physical Balances	Feed Grain Balance	X	X														
	Supply/Demand of Feed			X	X	X	X								X		
	Multi Cropping Land	X	X											X	X		X
Sectoral Constraints Policy Instruments	Feed Grain Import Quotas																X

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The model activities are (1) production of various annual crops, including forage and pasture management, disaggregated by types of technology; (2) perennial production and new planting; (3) livestock production; (4) temporary upland use of paddy land; (5) investment in farm machinery, in buildings, and livestock expansion; (6) feed grain imports; (7) financing, including savings and loans; (8) seasonal, nonagricultural employment or additional leisure time; and (9) various transfer activities.

The technology may either be traditional (at the beginning of the 1970's, Korea had basically a hand-and-ox technology) or mechanized with a 10 hp power tiller, including the necessary attachments. In the case of rice, a third technology, including a semiautomatic rice transplanter, is possible. So far there is only a limited experience with tiller cultivation on paddy land and the effects of better and deeper cultivation. The model assumes incremental yield increases on mechanized areas between zero and five per cent.[4]

The financing activities establish a step supply function of financial sources, originating with rising interest rates from (a) own capital, (b) long-term investment loan, (c) short-term loan for investment in working capital from either the banking system, or (d) from private sources.

The constraints of the model include the acreage of paddyland, summer upland, and winter upland (double cropping); an additional restriction on paddy temporarily convertible to upland; and the acreage of mature orchards and mulberry fields. Furthermore, there are limitations for human labor, draft cattle, and machinery during the two most important peak seasons (June and October) and an additional labor constraint for the rest of the year. Livestock herd sizes (Korean cattle, dairy, hog, poultry) cannot exceed the number of head raised in the past. In the current version poultry is introduced exogenously. A capital stock constraint for physical capital other than machinery calls for investment, if livestock, buildings, or working capital are expanded. Moreover, there are various feed balances and one feed grain import restriction in the model. Four constraints are relevant for the financial sector; namely, a liquid assets constraint counting accumulated savings--it can be used for short-term financing of production and long-term investment; an investment capital constraint for machinery investment and livestock expansion; and two minimum, self-financing constraints for investment in working capital and long-term capital stock, respectively.

The model reflects a suboptimal or cautious behavior of farmers by incorporating a mechanism of risk-aversion and restricted flexibility and, thus, establishing a lexicographic preference ordering. Maximization of expected profits is the allocation principle only insofar as two safety conditions are fulfilled:

(a) The possiblity of ruin resulting from a certain production pattern-- i.e., of receiving an income which does not cover unavoidable expenses--lies below a given probability threshold

(b) Year-to-year changes in cropping patterns and livestock production stay within certain flexibility constraints; i.e., do not exceed maximum deviations observed during a 10-year historical period

The risk-aversion approach is based on the assumption that farmers try to diversify their production pattern in such a way that the potential loss PL_j, expected under unfavorable weather and market conditions for any group J_i of production enterprises is not likely to exceed a fraction 1/k of the total admissible loss (activity LOSS).[5] The total permissible loss is the difference between the expected income from production $\left(\sum_j z_j \cdot x_j\right)$ and unavoidable expenses (= minimum income "MINI") for subsistence consumption, debt service, taxes, etc.

$$LOSS = \sum_{j=1}^{J} z_j x_j - MINI$$

$$\sum_{j}^{J_i} PL_j x_j \leq \frac{1}{k_i} LOSS \qquad i = 1, \ldots, N$$

Since this risk-aversion mechanism will only account mainly for the effects of yield and price fluctuations and not include the many other determinants of uncertainty and risk, a set of upper and lower bounds ($\overline{x}$ and $\underline{x}$) is introduced to avoid unreasonable fluctuations that cannot be explained by the aforementioned mechanism:

$$\underline{x}_j \leq x_j \leq \overline{x}_j \qquad j = 1, \ldots, J$$

Generally, the risk constraint will only hold if the corresponding flexibility constraint is ineffective and vice versa.

Similar to the flexibility constraints for production patterns, net investment in new machinery (tillers plus attachments, rice transplanters) is restricted and cannot exceed a certain proportion of the current stock of machines existing in any given year. This reflects the adoption behavior of farmers during the transition process, where learning and diffusion of innovations are accelerated as the number of previous adopters is increasing.

Internal Feedback, External Feedback, and Exogenous Variables: The Dynamics of Resource Allocation

In order to account for the dynamic properties of the sectoral adjustment and growth process, dynamic feedback operators and linkages are defined which relate the values of the objective function, matrix coefficients, and constraints to preceeding solutions of the programming model, to variables being computed in other parts of KASM, and to exogenously projected variables. Following is a brief review of feedback linkages for the objective function and the constraint vector. A formal representation follows in an appendix.

The objective function coefficients represent farmer anticipations of future costs and returns. Profit expectations of field crops are a function of exponentially lagged producer prices, one-period lags of yields, and the corresponding variable costs. For livestock production the objective function coefficients are equal to the previous yearly average of net returns during the mature production phase, minus proportional replacement costs, plus proportional salvage returns.

Investment decisions depend on the expected marginal value product and marginal costs. In the case of farm machinery, buildings, and livestock investment, the marginal value product is computed endogenously through production activities using the respective capital; hence, the objective coefficient includes costs for depreciation only. For investment in perennials (planting of orchards or mulberry fields), where yields are not immediately available, decisions to plant are based on the marginal value product imputed to the existing mature field in the previous year.

Finally, the objective function coefficients of all other activities, namely feed import and activities to establish intersectoral linkages on the credit and labor market, are determined exogenously. They refer to import prices, interest rates, and opportunity costs of labor.

The constraints of the programming model indicate the state of the system at the beginning of a period. While the total paddy area, as well as summer upland, is projected exogenously, upland for annual crops is also a function of endogenously computed areas with perennial crops.[6] Winter upland depends on the double-cropping potential of paddy- and upland.

Seasonal labor constraints are determined by the seasonal size of the agricultural labor force projected by the population component (POPMIG) and by the labor requirements of the new perennials not yet in production.

In order to account for learning effects due to mechanization, general agricultural research, labor scarcity, and rising educational levels, the efficiency of labor use is assumed to grow within certain limits. This is reflected in the model by gradually increasing the working time equivalent. A vintage approach is used to simulate the capacity development of machinery, namely power tillers plus attachments, for land cultivation and rice transplanters. The current total capacity per season depends on previous investments, while the unit capacity is determined by a depreciation schedule. Other capital stock is simply a function of initial conditions and net additions through investment. This includes mainly indigenous capital, such as livestock and buildings.

Technically maximum herd sizes of livestock (measured in female breeding units) are computed as a function of the actual herd in the previous year, of the potential net additions from the young female herd, and from livestock imports determined by policy. If the maximum herd size is not used, the difference is assumed to be slaughtered.

Pasture land, although in most cases collectively used by the villages, might become an important limiting factor for cattle and dairy herd expansion and is treated as a farm resource in the model. The capacity will depend on the rate of reforestation and public investment in upland development in general. It is projected exogenously [10].

A further set of constraints reflects the financial capacity of the farms, namely the availability of liquid assets, investment capital, and credit. Liquid assets are available to finance the current production (working capital), to increase the capacity of other farm assets (investment in machinery, buildings, livestock), and can alternatively be deposited in bank accounts. At the beginning of any period, liquid assets are computed as the sum of the previous working capital, minus repayment of short-term loans, plus savings out of previous income and bank accounts. The disposable income is defined as the actual agricultural value added, plus nonagricultural income, minus taxes, interest, and principle.

Both short-term bank loans and long-term loans can be limited exogenously. The current version, however, contains an internal rationing mechanism. The credits cannot exceed a certain proportion of the working capital and investments in new capital stock respectively. The level of the minimum income to be covered by returns from the farming sector equals a minimum subsistence requirement (a proportion of the previous average consumption) plus unavoidable expenses for debt service, interest payments, and taxes.

Flexibility and adoption constraints for production and investment patterns are a function of the previous year's optimal level of the respective decision variables and of the previous state of the system. For investment in mechanized technology, an adoption constraint is introduced to avoid unrealistically drastic increases in the stock of machinery, an assumption which seems particularly important in the current process of transition from traditional hand labor and draft cattle to mechanized technology.

Time-varying technical coefficients of the programming model, namely yields and feed requirements, are either projected exogenously or are derived from the crop technology change component (CHANGE). Yield projections are consistent with assumed fertilizer application rates for crop activities and feed input levels for livestock activities.

Production Accounting

Once the allocation of resources to various production activities is projected for any given year, output levels of 12 crop and 5 livestock commodities can be computed by simply multiplying activity levels by the respective actual yield levels. Similarly, the actual demand for various inputs (fertilizer, chemicals, fuel, concentrates) can be computed by enterprise and by kind of input. Actual yields and the corresponding unit requirements of inputs are projected either exogenously or endogenously in the CHANGE component. Total output by commodity, both gross and net, after subtracting farm losses, and total input by kind result from simple aggregation. They can be checked for consistency with national and sectoral accounts. Moreover, they are inputs to the national economy component (NECON). Multiplied by the respective commodity prices (from DEMAND) and by input prices, respectively, they yield "value of output" and "value of inputs," needed to compute income and other related performance variables.

Data Requirements for FRESAL

Following is a brief discussion of data needs for the farm resource allocation and production component. Inputs from other KASM components are excluded. For the remaining data a distinction will be made between initial conditions, constant parameters, and time-varying parameters or exogenous variables.

Initial Conditions

Initial conditions are required for the entire constraint vector of the annual allocation model. They include (1) land constraints, derived from official statistics published by the Ministry of Agriculture and Fisheries (MAF); (2) seasonal capacities for human labor--derived from POPMIG, draft cattle, and machinery, both from MAF statistics; (3) liquid assets, farm capital, and income, derived from the Farm Household Survey (FHS) and sectoral accounting data; and (4) flexibility constraints for cropping patterns and livestock production, derived from MAF statistics on historical cropping areas and production levels.

Constant Parameters

FRESAL uses a wide range of parameters related to production technology, input productivities, prices, and behavioral assumptions. Both positive and normative concepts are involved, which may explain some of the difficulties in obtaining real-world observations for these parameters. Almost none of them is constant in the real world. However, some of them are assumed constant due to a lack of data. Constant in time are mainly (1) parameters indicating the composition of some crop aggregates and intercropping rates in perennial fields, both derived from MAF statistics; (2) by-product yields (straw, vegetable leaves, bran) of crops; (3) mechanization costs and unit labor requirements for given technology levels, derived from a Report on Farm Mechanization in Korea [5] and survey data provided by the Farm Management Section at NAERI; (4) application levels of various livestock inputs--e.g., equipment, veterinary; (5) standard deviations of yields and prices for field crops; (6) flexibility coefficients for production patterns, derived from either historical time series or off-line trend projections (Currently, off-line trends are projected for egg and chicken production.); and (7) maturation delays of perennials.

Time-Varying Parameters

Exogenous variables and time-varying parameters are by definition based on off-line projections and, hence, establish the numerical conditions for the model projections. Such exogenous projections include (1) yields of annual and perennial crops, insofar as they are not provided by CHANGE, and the related variable input levels; (2) livestock yields, feed requirements, and fertility rates, derived from a Report on Feed Supply and Use of Livestock PRODUCTION [9] and farm management surveys done by NAERI; and (3) prices for variable inputs (not provided by NECON), interest rates, and opportunity costs of labor, indicating marginal values of leisure or additional off-farm employment opportunities.

Basic Model Results and Validation

This section contains a sample of model results for resource allocation and production. Base-run projections (1975-1985) are based on fixed price policies for rice, barley, wheat, cocoons, and tobacco. Other prices are market determined within given bounds. The major purpose of this section is not to arrive at particular policy conclusions. Rather, it is to demonstrate the model's potential to support policy analyses by providing information about the dynamics and consistency of structural change, as well as resource scarcities and productivities resulting from alternative policy measures and parameter assumptions.

The presentation of results concentrates on the most important trends and is almost entirely graphical. Where possible, it includes a nine-year historical reference period, indicating the observed patterns of change and enabling a visual time series comparison for four years. Running the model during a longer historical reference period was not possible, due to a lack of sufficiently accurate time series data. The overall validation and verification has been a part of component development from the beginning and cannot be discussed here in its full complexity. It included the confrontation of the logical model structure, of data assumptions, and the plausibility of results with the experience and knowledge of experts in NAERI, MAF, NACF, ADC, etc. Formal time series comparisons, although necessary and useful, cannot substitute this process, not only because it is very difficult to determine the model's degree of freedom (to deviate from observed patterns of change), but also because some of the policies and technical changes did not exist in the past.

The discussion of basic model results will be divided into the following categories: (1) trends in production patterns; (2) factor productivities, income, and income composition; and (3) interpretation of model results and experiences with the general approach.

Trends in Production Patterns

Generally the model explains the past trends in land allocation fairly well, with the exception of potatoes (Figure 5): at the given prices for the historical time period (1971-1974), the areas with barley (plus wheat) and pulses (plus other grains) continue to decline, whereas vegetables and industrial crops are increased in acreage. Potatoes, in spite of a steep price increase, decline in area. The area in rice expands at a slightly increasing upper bound in the model.

The projection from 1975 to 1985 is based on a specific set of price policy assumptions, mainly fixed high prices for rice, barley, and wheat. The main result of such a policy would be, after a time delay of one to two years, a reversal of the trend in barley area decline, substituting for industrial crops and tobacco, but also potatoes, which, under market conditions, would suffer a steady price decline to a lower

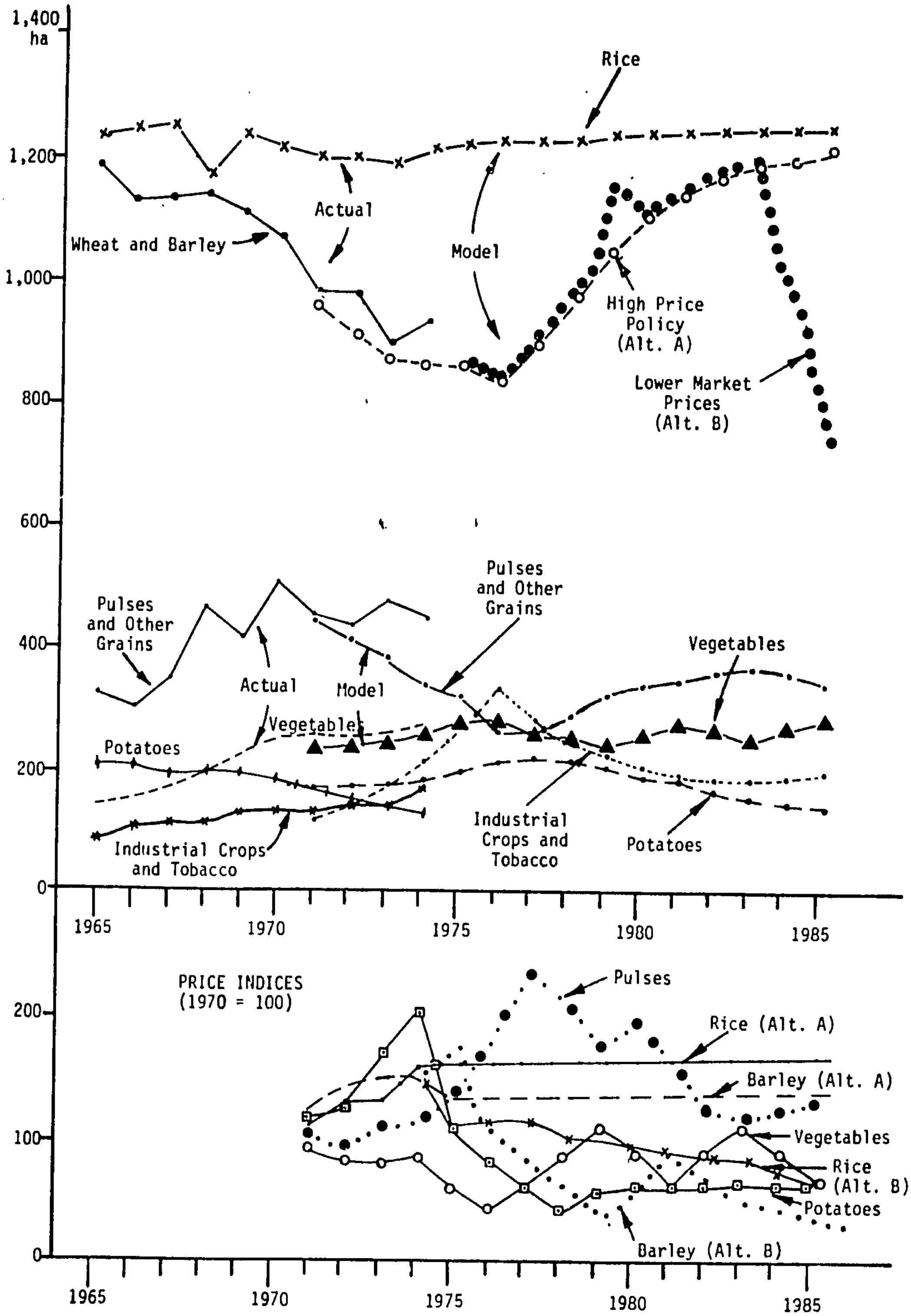


Figure 5. Basic Results for Annual Cropland Allocation with High Grain Price Policies for Rice, Barley, and Wheat (Alternative A) and Major Deviations for a Market Price Alternative (Alternative B)

bound. The vegetable area would continue to level-off around 240 thousand hectares. At the given low price elasticities of demand and the competitive position of vegetables implicit in the production data, the results demonstrate very clearly a cyclical dynamic behavior, with a two-period lag between prices and production response. Figure 5 also contains results for an alternative set of price policies, differing from the previous one by the assumption that rice, barley, and wheat prices are market determined. The result is a lower level of rice and barley prices; a slower increase of barley and wheat areas, with some unused double-cropping land; and, not shown in the figure, a substitution of feed grain imports by domestically produced grain. Production of rice and other crops is mostly unaffected, in spite of much lower rice prices.

Certainly, these results cannot be fully interpreted unless the effectiveness of the constraints and their respective shadow prices are taken into account. In fact, the dual solution indicates for this run, for example, that barley and wheat are generally the "residual users" of double-cropping land, since most competing crops are either bounded from above or below. More details on model interpretation will be discussed under the next two subheadings.

Figure 6 demonstrates some results on livestock production. Egg and poultry meat production are exogenously projected, since their competition with other agricultural products is very limited and, at the chosen level of aggregation of the model, difficult to specify realistically. Poultry production is mainly determined by the ratio of product to concentrate prices, the latter depending very much on world market prices, which are difficult to project. Earlier attempts to

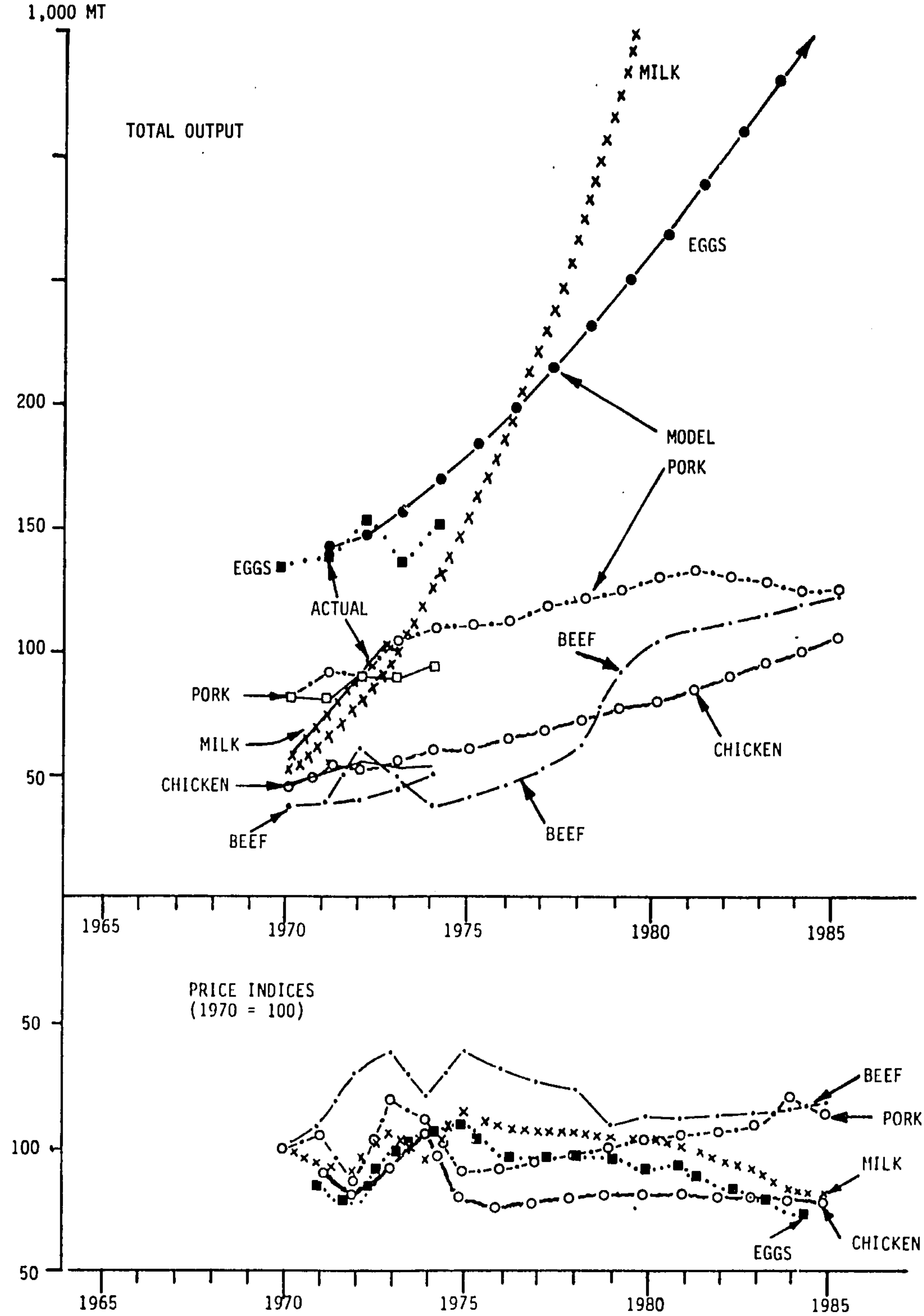


Figure 6. Basic Resul: for Livestock Production (Alternative A)

explain poultry production endogenously resulted, therefore, in fluctuations that seemed clearly unrealistic. It is assumed that the number of layers and broilers grow at the same rate. The higher growth of egg output results from the assumed growth rate of egg yields per hen.

For dairy, beef, and hogs, the model explains reasonably well the past development trends. The projections to 1985 show a rapid increase in milk production and a more modest expansion of pork and beef production, the latter fluctuating considerably around the trend. The prices, mostly market determined, remain relatively stable in spite of the considerable output growth, which seems a realistic reflection of the high income elasticities of demand for livestock products. The dual solution indicates that dairy production is growing along the maximal natural expansion path. At the assumed rate of yield increase, dairy remains profitable even at declining milk prices. Further research will be necessary to provide evidence whether this result is realistic or whether other cost items, more rapid declines in the income elasticity of demand, as well as limitations in the availability of high-quality roughage might lead to a decline in the growth rate of dairy production. Beef and hog production would, according to the model results, respond more sensitively to variations of prices and feed costs, with beef mainly stemming from traditional Korean cattle providing animal labor at the same time.

Factor Productivities, Income, and Income Composition

Certainly the model is not yet sufficiently tested to allow final conclusions concerning the future income of Korean agriculture and the contribution of various resources. However, some basic insights can be gained from the results, and key areas for further research and testing can be indicated.

While the real growth rate of agricultural value added is overestimated for the reference period from 1971 to 1975 (8.7 per cent compared to 4.5 per cent), the base-run projection from 1975 to 1985 of 4.5 per cent seems plausible and comes close to official plan figures. The overestimation may be caused by incorrect specification of initial conditions.

Table 2 contains some information concerning the level of the agricultural value added (at 1970 prices), its distribution by commodity groups, and the relative contribution of various groups of resources. On the commodity side, the share of livestock products is gradually increasing and, thus, reflecting the shifting preference of consumers with rising income. The factor income distribution is computed by taking the physical resource levels valued at their imputed marginal value productivities. These marginal-value productivities are derived under the behavioral assumptions of "cautious optimizing within bounds" and, hence, are not necessarily predictions of actual factor prices. However, they are useful in interpreting the relative importance of various groups of resources and in evaluating economic effects of marginal changes of resource levels. Except for the initial year, where higher

Table 2. Projected Agricultural Income and Resource Productivities

Performance Variables	1971	1972	1975	1980	1985
Agricultural Value Added					
Billion Won	697	776	989	1,302	1,551
Index (1971 = 100)	100	111	142	187	222
Distribution by Commodities					
Crops (percentage)	84.4	84.7	83.5	78.5	76.5
Livestock (percentage)	12.2	12.2	14.0	19.7	27.0
Residual (percentage)	3.4	3.0	2.4	1.8	1.5
Contribution of Various Resources (in percentages)					
Land (Paddy, Annual, and Perennial)	68.9	50.8	56.8	53.6	57.1
Labor	43.3	39.3	33.4	30.9	31.7
Capital (Livestock, Machinery, Liquid Assets)	6.3	2.3	1.6	7.3	10.1
Crop Rotation, Behavioral and Technical Constraints	-18.5	7.5	8.1	8.2	1.1
Selected Shadow Prices					
Paddy (th. won/ha)	202	227	320	441	492
Upland (th. won/ha)	28	29.2	36	40	49
Internal Interest Rate (percentage)	6.4	5.1	1.0	5.1	5.5

winter upland rents are imputed from vegetable production, the physical annual and perennial land input accounts for approximately 55 per cent of the total agricultural value added, indicating a relatively high land scarcity. Labor is receiving a slightly decreasing share of 30 to 40 per cent, while the income share of capital, so far as it is included in the model--namely livestock, machinery, and liquid assets (working capital and savings)--is relatively small but increases from 2 to 10 per cent between 1972 and 1985. The low share during the initial four years is mainly caused by the very low real interest rates that were computed after accounting for the observed inflation rates. The remaining income would, under model conditions, be imputed to crop rotation, risk, and flexibility constraints and technical restrictions. Positive shares indicate upper bound effects; negative shares measure lower bound effects. Except for the first year, they do not contribute by more than 5 to 10 per cent; i.e., upper and lower bounds almost compensate each other.

Some concluding comments relate to the labor income. As mentioned in Chapter 8, off-farm migration is projected exogenously in the current version and is not affected by the agricultural income projected endogenously in this component. Since the projections with respect to migration are rather cautious and refer mainly to rural-urban migration, decision variables were introduced into the allocation subcomponent model which simulate additional seasonal off-farm employment, possibly favored by future rural development policies. The same variables might also be interpreted as leisure activities carried out whenever the marginal value product of labor falls below a certain limit. In fact, the base-run results indicate that the income share of labor is in most cases determined by these exogenous opportunity costs, except for the transplanting season in June, when labor is sometimes more scarce and priced higher than the external opportunity costs. As the figures in Table 3 indicate, the main decline in agricultural manpower is assumed to take place before 1975. After 1975 the projected rate of decline is very small (0.08 per cent) and might be overcompensated by efficiency increases. Under the base-run assumptions (labor opportunity costs in 1970 at 25 won per hour, growth rate at 40 per cent per year), the average rate of on-farm utilization of this labor force would be only 50 to 60 per cent. Leisure or additional off-farm employment would make up 50 to 40 per cent. However, during the peak seasons, the average rate would increase rapidly to almost 100 per cent, causing a substantial mechanization rate during the 1970s, which would later proceed much more slowly. Much higher rates of mechanization and higher additional off-farm employment would result, if the opportunity costs were doubled in level and rate of change (Run C).

This discussion exemplifies the need for detailed interpretations of results which can lead to further model improvements. In order to explain migration endogenously, for example, a formal linkage between FRESAL and POPMIG might be considered.

Interpretation of Model Results and Experiences with the General Approach

In this section some comments will be made concerning the strength and the shortcomings of the general approach. Moreover, it will be

Table 3. Mechanization and Rates of Labor Utilization at Low (Run A) and High (Run C) Opportunity Costs of Labor

	1971	1975	1980	1985
Agricultural Manpower in Peak Seasons (thousands of man-equivalent units)	5,514	5,062	5,038	5,024
RUN A: Labor opportunity cost = 25 won/hour, Growth rate = 4 percent				
Used/Available Farm Labor				
Annual (percentages)	47	51	53	60
Peak Seasons (percentages)	88	97	95	92
Number of Tillers	11.0	168.7	171.2	164.5
RUN C: Labor opportunity cost = 50 won/hour, Growth rate = 8 percent				
Used/Available Farm Labor				
Annual (percentages)	39	31	36	39
Peak Seasons (percentages)	78	65	71	67
Number of Tillers	11.0	281.8	369.4	317.5

argued that it is very important to interpret results comprehensively and that any separate use of partial results might lead to wrong conclusions and thus be dangerous. Finally, it will be shown how the model application could be adjusted gradually to the decision process within the planning unit.

Basically it is true for any quantitative model that deviations between reality and model results can be due to false behavioral assumptions, an incorrect or incomplete specification of the system structure, aggregation errors, and/or false data. All of these sources of errors may be more or less relevant for FRESAL and should receive further attention. The behavioral assumption, according to which resource allocation results from "cautious optimizing," is difficult to test but appeared to be consistent with impressions from many farm visits and the experiences of Korean farm management experts. These contacts led to several modifications of the model, examples being the assumption to use exponentially lagged price expectations and to introduce an explicit risk-aversion mechanism in order to explain better the observed diversification of cropping patterns. Actually, this procedure may highlight the general strength of the microeconomic approach, enabling a good communication on data and assumptions with farmers, farm management experts, and even administrators.

Areas where the model structure might be incomplete or incorrect are related to (1) the various land categories, which should be distinguished according to existence of irrigation, rearrangement, or possibility for further double-cropping; (2) mechanization, where a further disaggregation into different kinds and levels of technology might be useful; (3) liquidity and financing, where seasonal liquidity and external credit rationing may be examples for refinements of model structure. All these additions would, in conjunction with data improvements, reduce the importance of exogenous flexibility constraints in explaining the diversification of production patterns which one observes in Korean agriculture. Whether or not an explicit modeling of subsistence behavior, which still exists in some parts of the farming sector, would also contribute to this explanation is another question needing further research.

Certainly a national model of the agricultural sector suffers from aggregation errors. Natural conditions are assumed to be homogeneous within the country, and labor is assumed to be completely mobile between farms. This may lead to overestimations of agricultural production potential and the flexibility of the system. If data were available, a regional disaggregation, as indicated earlier in this chapter, might reduce some of these aggregation errors. Furthermore, it would enable the planning unit to introduce regional policies and regional differences in opportunity costs of labor, etc.

A further shortcoming of the current model version is its data base. Many cost items are not well known on a commodity or enterprise basis and will have to go through further consistency tests. This holds, for example, for production function data, mechanization costs, and labor requirements. Uncertainty exists also with respect to initial financial conditions, the farm capital requirements for activities not directly related to production as contained in the model (e.g., farm buildings, storage, irrigation), or propensities to save. Using the current data assumptions, the projected composition of field crops is very much determined by the gross income per hectare. Even after several revisions, the data indicate an extremely wide range of gross incomes between crops, resulting in a relatively small impact of labor requirements, mechanization costs, capital, and profit variability on the cropping patterns. Rice and vegetable prices, for instance, could vary considerably without affecting this pattern. Although this may be quite realistic, at least for rice, and thus indicates a range for various price policies, the scale of the resulting differences in land productivities should be used as a guide for further data checks.

Some final comments relate to model interpretation and application. To interpret projected allocation patterns in terms of the determining factors and system stability, it is important to take into account the constraint structure and the dual solution (shadow prices) at the same time. This comprehensive approach helps explain whether a certain production activity would be limited by physical, economic, or behavioral factors and how sensitive the solution would be to changes of any relevant variable. This will be demonstrated for those field crops competing for winter upland.

Figure 7 shows the marginal value productivities (MVP) of winter upland planted with four competing crops, namely winter vegetables, industrial crops, wheat, and barley. The MVP of the physical winter upland constraint is always shown as a reference, and the individual MVP's for the crops are derived as the sum of this MVP of physical winter land and of the respective flexibility.

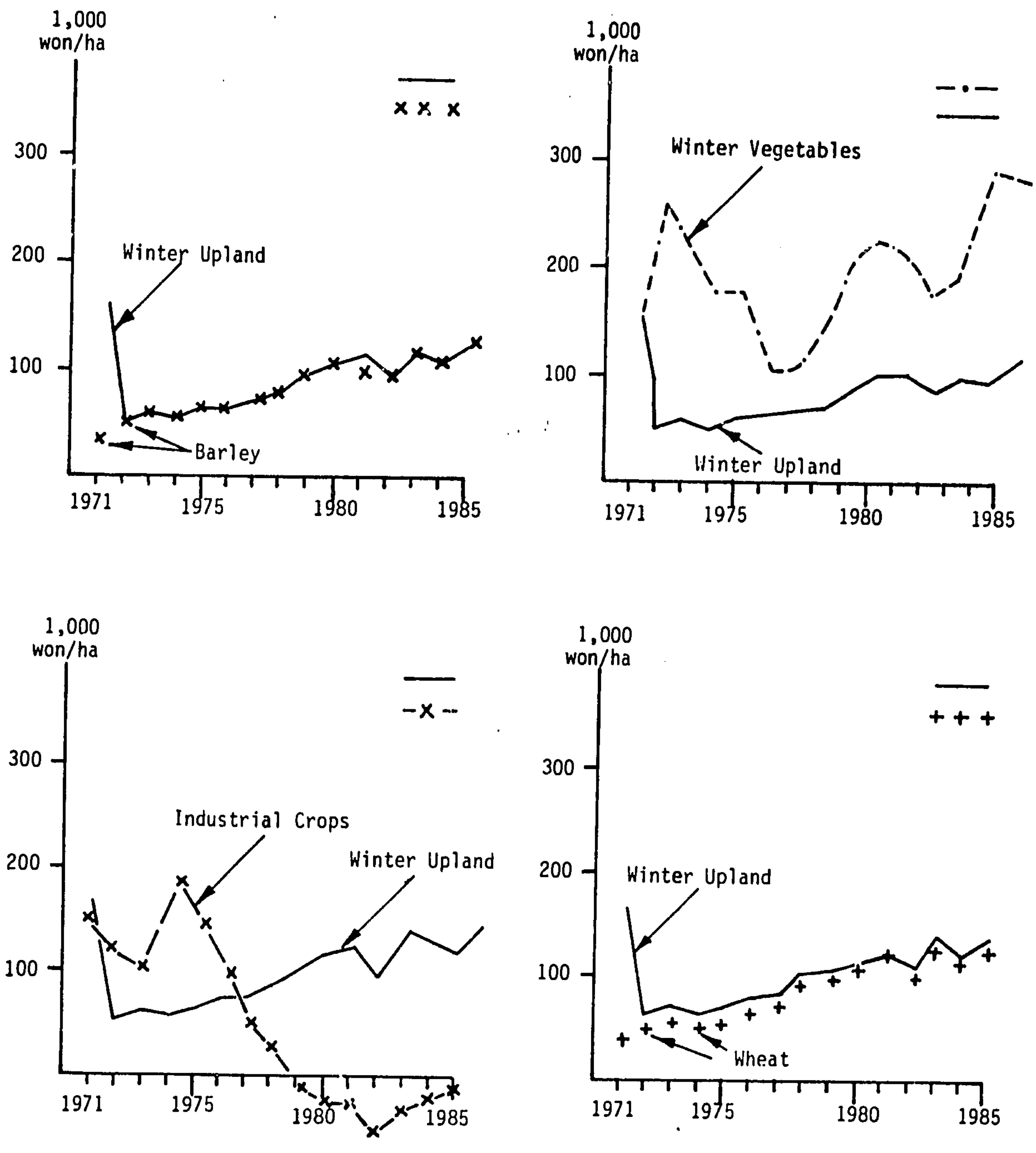


Figure 7. Shadow Prices (Marginal-Value Productivities) of Physical and Behavioral Constraints for Crops Competing for Winter Upland

Thus, whenever no flexibility bounds restrict a certain cropping area, the two MVP's coincide. The graphs indicate that this is true in most years for barley and, with small deviations, for wheat. Winter vegetables have a clear comparative advantage throughout the projection period, whereas the MVP of land in industrial crops is high at the beginning and declines steadily to become even less competitive than barley and wheat cropping alternatives. After 1980 industrial crops even encounter marginal losses, which means that the remaining income per hectare after deducting variable costs and opportunity costs for all nonland resources would be negative. This example demonstrates clearly that industrial crops are switching from an upper to a lower bound and would, without flexibility bounds, first replace wheat and barley, then be replaced by these crops in a second phase, and disappear completely in the last period. With the exception of two years, barley would be the "residual crop" occupying the area remaining when the other crop areas are restricted by flexibility bounds.

Similar analyses to that indicated above could be done for all other activities, including other nonbehavioral constraints. The insight gained by this kind of analysis can be used for sensitivity and policy analysis. Such analysis may point out remaining data deficiencies and cost items left out or incorrectly quantified. This relates to cases in which the resulting productivity gaps and trends of changing production patterns seem unrealistic. Another improvement area revealed by such analysis might be a need for a respecification of the model and search for further, thus far unidentified, cost and return items.

Another useful result of such analysis relates to policies. Productivity differences, for instance, can be used to determine the range of price changes needed to achieve a desired reallocation. Winter vegetable areas, for example, would not be affected by price declines or cost increases, as long as the surplus return over industrial crops (in the initial years) and barley (in later years) remains positive. In the case of barley, for example, price policies leading to lower prices would in most years not affect the areas of other crops, and barley areas themselves would remain unchanged as long as the price decline would not reduce the land MVP to zero. Further price declines would cause double-cropping potential to be unused, as in the example shown in Figure 5 under the free market price alternative for barley.

This illustration may suffice to emphasize the need for comprehensive model interpretations. To conclude, for example, that winter vegetable production is not increased when prices are raised, while the model assumes an upper bound, is equally misleading as to conclude that wheat production tends to be replaced by barley in the absence of a lower bound, while the dual solution indicates only negligible productivity differences between barley and wheat.

Although the model analyst should try to reduce the importance of the flexibility constraints by specifying explicitly more physical, technical, economic, and behavioral structure, the combination of exogenous and endogenous specification enables a flexible use in the practical planning process. Basically, the flexibility constraints stand for factors influencing resource allocation which are not explicitly known or not quantifiable with respect to their cause-and-effect relationships.

The planning unit, for example, the MAF, can use them to impose any boundaries on the system that seem realistic. Thus, the planning process can proceed iteratively and stepwise, as it does traditionally within most governments. Three modes can be conceived. In mode 1 exclusively exogenous trend projections can be used, leaving no flexibility to the model's endogenous economic mechanisms. In this case the equation system is used to test the consistency between the projections with respect to resource use (mainly land, labor, capital), feed supply and demand, fertilizer demand, etc. Likewise, the resulting shadow price and cost structures can be tested for plausibility. When used with current or historical production patterns, mode 1 can be a very useful means to test the data base of the model. In mode 2 the model-user can define relatively small flexibility coefficients, allowing some economically determined reallocation, which he can then interpret in the way mentioned before. In mode 3 the flexibility constraints can be widened or even dropped to allow a far-going endogenous explanation of the reallocation process. This mode of operation requires only a few or no prespecifications or assumptions concerning the future production patterns on the part of the planning unit.

Tentative Conclusions and Recommendations for Further Research

A dynamic, microeconomic model of farmers' decisions with respect to resource allocation and production was developed as a component of KASM. The major objective of this component is to simulate the year-to-year allocation of farm resources under the condition of prespecified input-output relationships and initial conditions with respect to resource levels.

The component can be used flexibly; i.e., as a separate model or in an interactive mode, with input and output linkages with other KASM components. The results presented in this chapter illustrate mainly the market feedback recursively linking endogenous market prices and the respective supply response.

The presentation of results indicated both some positive features and some weaknesses of the model at this stage. The positive features are summarized first. Projections of resource allocation allow for automatic consistency checks for supply and utilization of inputs and fixed resources. Moreover, the market linkage establishes consistency between income and population-determined changes in consumer demand and the resulting resource allocation and production responses. The projections include further information about the economic forces underlying growth or decline of resources measured as shadow prices that cannot be obtained by nonsimultaneous system models. The results, although not yet fully acceptable, seem to support the basic hypothesis of rational behavior under limited information and the competition mechanism among human, animal, and mechanical power regulating the process of technical change in agriculture.

Conceptually, a model like this will never be complete and final. However, it might be considered as a useful basis for further analytical research and policy analysis, as well as a comprehensive information system integrating micro-level farm management data and macro-level information for the sector as a whole.

Several weaknesses of the model have been pointed out, which should be subject to further research. The most important area for research is related to intensive data consistency checks and general improvements of the data base. This relates mainly to production costs, mechanization, and labor requirements. A close cooperation with farm management experts will be useful. A second area relates to the aggregation level, where a breakdown into regions appears to be useful. Other needs for more modeling work include improving the structure which relates to subsistence and risk-aversion behavior, financing, and mechanization.

Besides these basic and obvious priorities, directions of research will depend on the specific problems and subject matter areas to which the model is to be applied. Thus, a close interaction of systems scientists, economists, farm management experts, and policy-makers will be permanently needed if the model should become what it is intended to be: a conceptual and theoretical basis, with sufficient flexibility for policy analysis and application to changing problems in the field of agricultural production.

APPENDIX

Internal Feedback, Exogenous Feedback, and Exogenous Variables: The Formal Structure of Dynamic Linkages

1. Objective Function Coefficients (z)

--Production activities

$$z_{jt} = z_{jt}\left(\hat{p}_{jt}, yld_{j,t-1}, cost_{j,t-1}\right) \qquad j\varepsilon AP$$

$$\text{with } \hat{p}_{jt} = \hat{p}_{j,t-1} + \frac{1}{\lambda}\left(p_{j,t-1} - \hat{p}_{j,t-1}\right) \qquad 0 < \lambda < 1; j\varepsilon AP$$

where AP is the set of all production activities, p is the producer price (endogenous to the DEMAND/PRICE component), yld is the yield per unit, and cost the variable cost, including replacement. The parameter λ indicates the time constant of the distributed delay.

--Investment activities

$$z_{jt} = z_{jt}\left(r_{i,t-1}, v_{jt}\right) \qquad j\varepsilon AI;\ i\varepsilon CI$$

where to each j corresponds one specific constraint within the set CI of resources. AI is the set of investment activities, and r is an optimal shadow price; v is an exogenous variable indicating depreciation rates.

--Other activities (financing, transfers, etc.)

$$z_{jt} = z_{jt}\left(v_{jt}\right) \qquad j\varepsilon AL$$

where AL is the set of all other activities and v is an exogenous variable.

2. <u>Constraint Vector Coefficients (y)</u>

--Land areas

Generally, for physical land constraints,

$$y_{it} = y_{i,t-1} + v_{it} - \alpha_i \left(\sum_{j \in AR} x_{j,t-sj} \right) \qquad i \in CA$$

where y is an element of the constraint vector; CA is the set of area constraints; v stands for area changes due to land development or withdrawal for industrial urban land use; AR is the set of perennial planting activities; α_i is the proportion of perennials using land category i ($\alpha_2 = 1$ for upland, $\alpha_1 = 0$ for paddy). Winter land (double cropping) y_3 is a weighted average of these physical land constraints:

$$y_{3t} = \sum_{i \in CA} p_i y_{it}$$

where p_i are double-cropping ratios.

--Labor

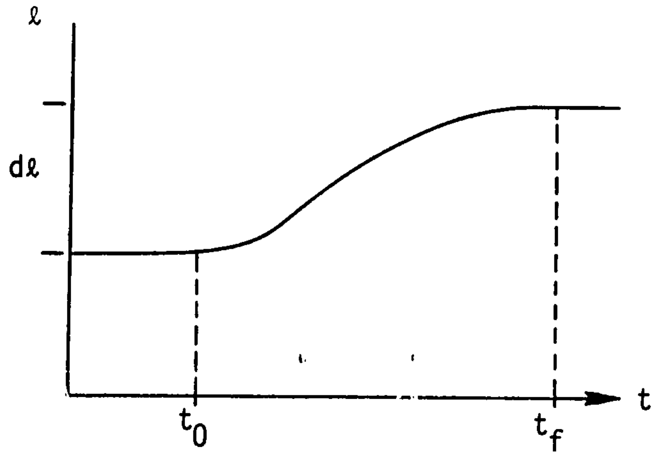
$$y_{it} = \ell_{it} \cdot AGMP_t - \sum_{j \in AR} \sum_{s=1}^{N_j} a_{ijt} x_{j,t-s} \qquad i \in CL$$

where CL is the set of seasonal labor constraints; AGMP is the seasonal agricultural labor force; N_j is the time (years) of prematureness of perennials; a_{ij} is the labor requirement of activity j in season i; and ℓ_{it} is working time equivalent in hours per season and man-equivalent unit.

The working time equivalent ℓ is gradually increasing over time to reflect learning and efficiency improvement. Let ℓ_0 be the current time equivalent, $d\ell$ the maximum increase of ℓ, t_0 and t_f the initial and final period of efficiency changes; then ℓ can be approximated from the following function:

$$\ell_{it} = \ell_{i0} + 0.5 d\ell_i [1 + \sin\left(\pi \frac{t-t_0}{t_f-t_0} + 1.5\right)].$$

Graphically this is shown below:



Approximation of Efficiency Increases of the Agricultural Labor Force

--Machinery

The machinery capacity per unit of machinery aggregate i in peak season m is expressed in seasonal labor per unit α_{im} times the effective number of units. The effective number of units depends on the previous net investment x_{ij} and the depreciation schedule λ_i. Replacement of machinery, exceeding a maximum lifetime S_i (e.g., 7 years for tillers) is exogenous:

$$y_{im,t} = \alpha_{im}\left(\sum_{s=1}^{S_i} \lambda_i^s x_{ij,t-s} + \lambda_i^1 x_{ij,t-S_i}\right) \qquad i\varepsilon CM;\ j\varepsilon IM;\ m = 1,2$$

where CM is the set of machinery packages and IM the corresponding set of investment activities.

--Other Farm Capital

$$y_{it} = y_{it_0} + \sum_{s=t_0}^{t} x_{ij,t-s} \qquad i\varepsilon CV;\ j\varepsilon IC$$

where CC is the capital stock and IC is the corresponding investment, both measured in monetary terms at constant prices.

--Technically maximum livestock herd sizes

$$y_{it} = x_{j,t-1} + \beta_i x_{j,t-s_j} + v_{jt} \qquad i\varepsilon CV;\ j\varepsilon AV$$

where to each i corresponds one specific j; CV is the set of livestock herd constraints; AV is the set of livestock production activities; β is the net rate of potential herd expansion per female livestock unit; v_j are imports; s is the maturation time (years) of young female animals.

--Liquid assets

$$y_{\ell,t} = \sum_{j\varepsilon AP} cost_{j,t-1_i}\ x_{j,t-1} - x_{sp,t-1} - x_{ba,t-1} + \sigma DIPI_{t-1} + s_{ba,t-1}$$

where $y_{\ell,t}$ is the constraint for liquid assets; AP is the set of all production activities, including internal transfer and input purchases; x_{sb} and x_{sp} are levels of short-term loans from banks and private sources, respectively; σ is the marginal propensity to save; s_{ba} is the level of bank deposits; and DIPI is the disposable farm household income.

The disposable income DIPI, is defined as agricultural value added, VA; plus nonagricultural farm income, INNA; minus taxes, TAX; interest and principle on long-term loan, PINT and NDS, respectively:

$$DIPI_t = VA_t + INNA_t - TAX_t - PINT_t - NDS_t$$

where VA is a function of the levels of production activities, actual yields, and variable costs, including interest on short-term loans and wages for hired labor. NDS and PINT are depending on the long-term indebtedness of the farm sector, determined by previous levels of the respective loan activity.

--Minimum income

$$y_{M,t} = \mu(1-\sigma)DIPI + NDS_{t-1} + PINT_{t-1} + TAX_{t-1}$$

where $y_{M,t}$ is the minimum income necessary to cover unavoidable expenses; μ is the ratio between subsistence and actual consumption; σ is the average savings rate.

--Flexibility constraints

$$y_{i,t} = (1+b_u)x_{j,t-1} \qquad i\varepsilon UB;\ j\varepsilon AP$$

$$y_{i,t} = (1-b_\ell)x_{j,t-1} \qquad i\varepsilon LB;\ j\varepsilon AP$$

where UB is a set of upper bounds; LB is a set of lower bounds; AP is the set of all production activities. To each i there corresponds one particular activity j or group of activities belonging to the same crop category. b_u and b_ℓ are maximum change rates.

-Technology adoption

$$\alpha_{i1}x_{ij,t} \leq y_{a,t} = c_i y_{i1,t} \qquad i\varepsilon CM;\ j\varepsilon IM$$

where y_a is an adoption constraint, c_i is the maximum adoption rate, α is the unit capacity in seasonal hours (per season 1), IM is the set of investment activities, and CM is the corresponding set of machinery capacity (in hours).

FOOTNOTES

[1] The price vector, generated endogenously by a simultaneous market model subject to a budget constraint, is in fact the basic dynamic link in the model. Previous applications of recursive programming with single demand equations were presented by Mudahar [8].

[2] For the theoretical background of this approach and applications to development planning see, for example, [1, 3, 4, 6].

[3] In a regional mode this would in most parts correspond to one regional block of the matrix in Figure 4.

[4] For problems of farm mechanization in Korea, see [7].

[5] The approach is based on [2].

[6] More precisely, the model contains a distributed lag submodel to compute the cohort structure of perennials.

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CHAPTER 12

THE DEMAND-PRICE-TRADE COMPONENT OF THE KOREAN AGRICULTURAL SECTOR MODEL

Lloyd D. Teigen
Michael H. Abkin

This chapter describes the Demand-Price-Trade (DEMAND) component of the Korean Agricultural Sector Model (KASM), its information requirements, the variables it calculates, time-series tracking tests, and further areas in which the component can be revised and extended.

Component Description

The flow of information between DEMAND and the other components of KASM is shown in Figure 1. Domestic supply, population, and lagged income are major inputs into DEMAND. Food consumption, nutrition, prices, and agricultural trade flows are the principal outputs from DEMAND.

The major elements and computing sequence in DEMAND are shown in Figure 2. DEMAND projects farm demand, nonfarm demand, and trade, consumption, and nutritional accounting. In addition to a number of government policy instruments, production, population, and income are the major external forces, as represented in the diagram, which act on the component.

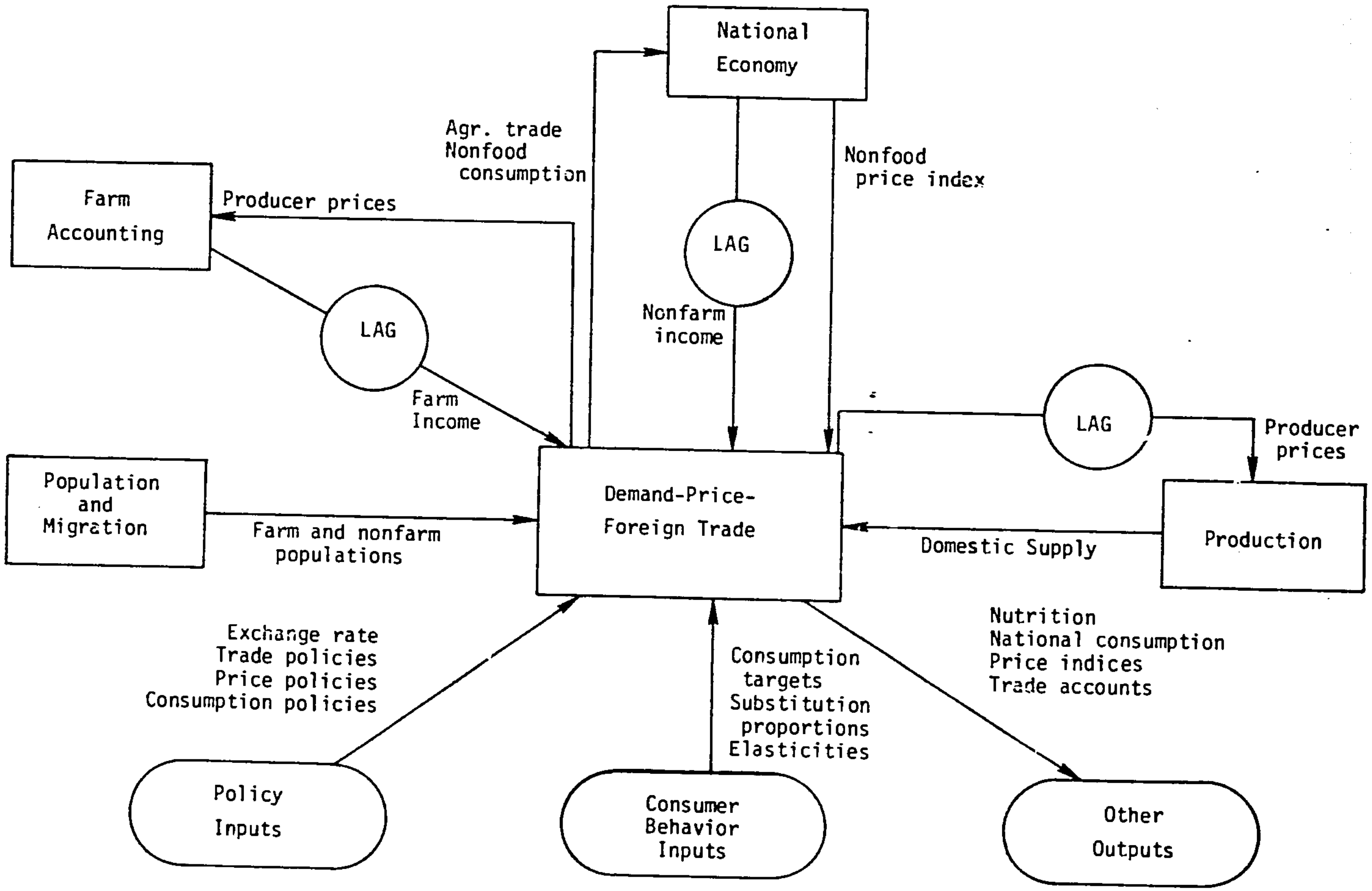

Figure 1. Major Linkages between the Demand-Price-Foreign Trade Component and the Rest of the Korean Agricultural Sector Model

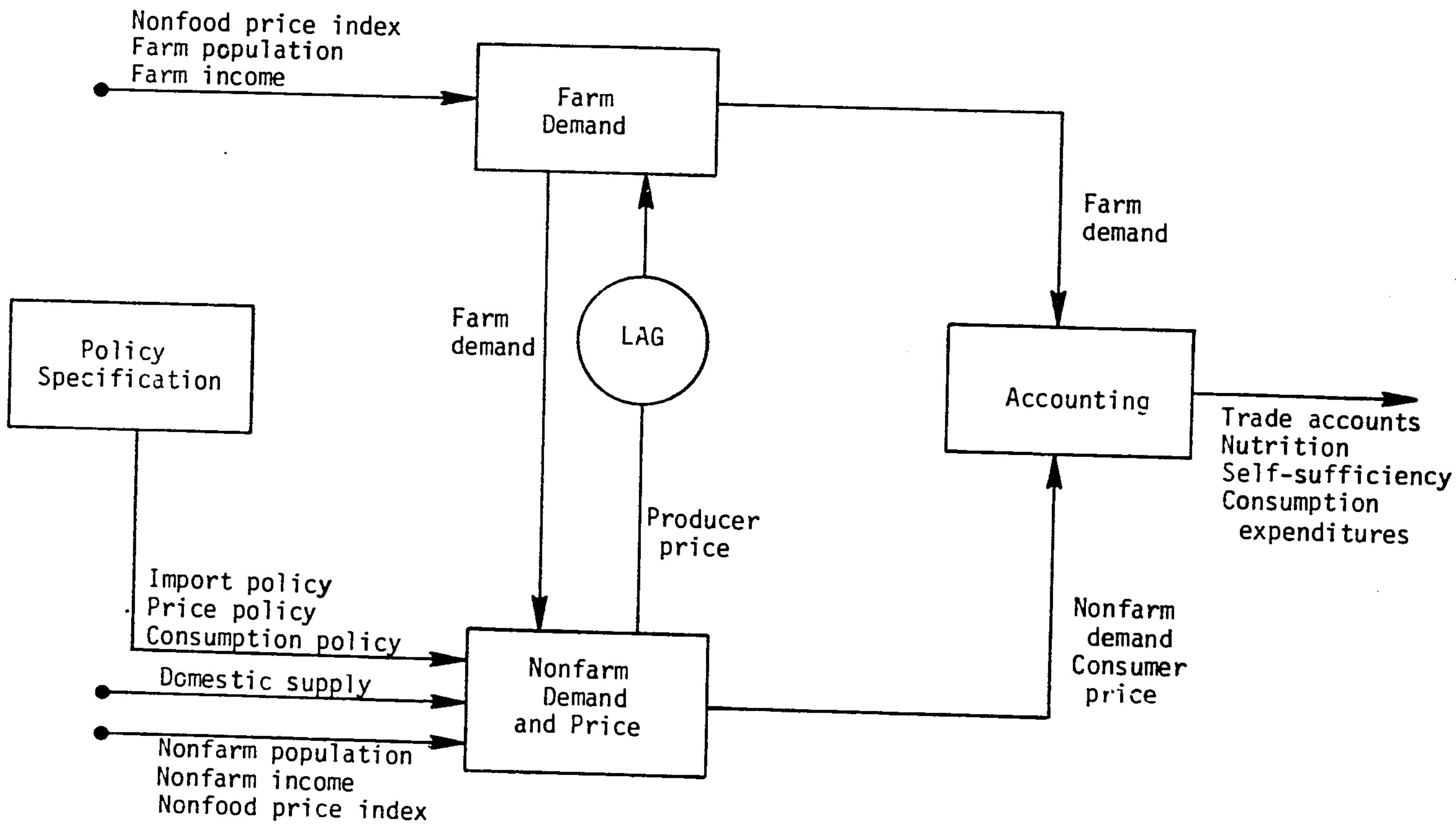

Figure 2. Schematic Diagram of the Demand-Price-Foreign Trade Component

The heart of DEMAND is a system of consumer demand equations for food commodities for farm households and for food and nonfood commodities by nonfarm consumers. World import and export price projections link these domestic relationships to the world market and also act as bounds on internal price variations. The actual import or export levels are assumed not to affect world price levels for the commodity groups.

The farm food demand component assumes subsistence behavior by Korean farm families. In other words, farm demand does not compete with urban demand and depends on lagged farm prices and income rather than current consumer prices and income. Indeed, farm consumption is subtracted from domestic supplies before the urban market is considered.

The nonfarm food demand component calculates equilibrium prices and consumption levels consistent with government policies, given the projected levels of domestic supplies, income, population, and farm consumption. For any commodity, the government policy may affect either price or quantity variables, but not both. When the policy set has been determined, a matrix inversion approach simultaneously solves all demand equations together with an expenditure constraint.

Price and consumption policies in Korea, as elsewhere, have many, sometimes conflicting, objectives. Increased domestic production and high producer income may be the objective of higher producer prices. Reduced food imports and foreign exchange costs may be the objective of import controls, higher consumer prices, and administrative measures. Reduced inflation, controllin industrial wage costs, and maintaining the ompetitive position of e port industries may be the goal of consumer price controls.

In order to determine the results of these and other instruments of policy, a number of policy options have been built into DEMAND. For each commodity four mutually exclusive policies and two independent policies are defined.

The mutually exclusive policies are

1. Per capita consumption may be set and price and import/export effects calculated

2. Import/export levels may be set and consumption and price effects calculated

3. Consumer price level may be set and effects on imports and nonfarm consumption levels calculated

4. Consumer price level may be bounded by either world prices or prior domestic prices *and* import/export levels set and price levels calculated, deferring to the price bounds if the two objectives conflict

The independent policies are

1. Government reserve stock management policies may be changed and the resulting effects on consumption, price, and import/export levels calculated

2. Producer price may be set by policy or linked to market price and the effects on farm consumption and the nonfarm market calculated

Each commodity must have one and only one policy from the "mutually exclusive" set and may have either policy (or both) from the "independent" set. These policy options are commodity specific, so that the policy for rice may differ from that for barley. A "default" policy set controls the model in the absence of a specific alternative policy.

Table 1 illustrates the 16 policy choices now available for each commodity. For each of the mutually exclusive policies, the

Table 1. Policy Options in DEMAND*

Mutually Exclusive Policies	Independent Policies: Producer Prices Set by Market — Standard Carry-over Policies	Independent Policies: Producer Prices Set by Market — Alternative Carry-over Policies	Independent Policies: Producer Prices Set by Policy — Standard Carry-over Policies	Independent Policies: Producer Prices Set by Policy — Alternative Carry-over Policies
1. Per capita consumption set by policy	X	X	X	X
2. Import/export levels set by policy	X	X	X	X
3. Consumer price levels set by policy	X	X	X	X
4. Consumer prices bounded and import/export levels set by policy, unless bounds are violated	X	X	X	X
4' Consumer prices bounded and per capita consumption set by policy, unless bounds are violated	Not Programmed			

*Each X is a policy option.

decision-maker can choose either kind of producer price policy and either kind of carry-over policy. One and only one of the mutually exclusive policies must be chosen for each commodity. Mutually exclusive policy 4 combines elements of 2 and 3. After the price bounds and import/export targets have been set by policy assumption, policy 4 operates like policy 2 unless the bounds are violated. In this case, the price is set at the nearest bound and policy 4 operates like policy 3. Policy 4' would combine similar elements of 1 and 3 but is not programmed into the system at present.

The theoretical construct for DEMAND is described below. Except for the values of the numerical coefficients,[1] the farm and nonfarm demand equations are identical. Thus, only one description of the theoretical process is needed.

Per capita consumption of each food commodity is related to the price of that commodity, prices of substitute food commodities, per capita income, and nonfood prices. The elasticity of own-price response[2] is constant for each commodity. The income elasticity depends on consumption levels such that the closer actual consumption is to a targeted consumption level, the smaller is the income response. This behavioral assumption insures that consumption does not increase without bound as income increases and that consumption patterns in the long run remain consistent with reasonable expectations of long-run calorie and protein intake [11]. The substitution elasticities[3] across food demand equations are constrained so that the partial derivative of consumption of one commodity with respect to that of another commodity is constant. In mathematical terms,

$$\frac{\partial q_i}{\partial P_j} = b_{ij}\frac{\partial q_j}{\partial P_j} \qquad \text{or} \qquad \frac{\partial q_i}{\partial q_j} = b_{ij} \tag{1}$$

In their linearized, difference equation form for simulation in DEMAND, the consumption functions are,

$$\begin{pmatrix} q_1 \\ q_2 \\ q_3 \\ \cdot \\ \cdot \\ \cdot \\ q_n \end{pmatrix} = \begin{pmatrix} 1 & b_{12} & b_{13} & \cdots & b_{1n} \\ b_{21} & 1 & b_{23} & & b_{2n} \\ b_{31} & b_{32} & 1 & & b_{3n} \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ b_{n1} & b_{n2} & b_{n3} & \cdots & 1 \end{pmatrix} \begin{pmatrix} m_1 & 0 & 0 & \cdots & 0 \\ 0 & m_2 & 0 & & 0 \\ 0 & 0 & m_3 & & 0 \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ 0 & 0 & 0 & \cdots & m_n \end{pmatrix} \begin{pmatrix} P_1 \\ P_2 \\ P_3 \\ \cdot \\ \cdot \\ \cdot \\ P_n \end{pmatrix} + \text{income and intercept terms} \tag{2}$$

where:

$$m_i = \varepsilon_{ii} q_i(t-1)/P_i(t-1) \tag{3}$$

is the own-price partial derivative and

$$\sum_{i \neq j} b_{ij} = -\alpha_j \tag{4}$$

is the proportion of the change in the j^{th} food consumption which is compensated by all other foods following a change in the j^{th} price.

The effect of nonfood price on food demand is obtained somewhat indirectly. Income and food prices are deflated by the nonfood price index in order to maintain the homogeneity condition. In the farm demand component, the deflation is explicit. For nonfarm demand, however, the deflation is implicit in that the nonfood cross-demand elasticity is computed as the negative sum of all price and income elasticities for each food commodity.[4]

For the farm food demand component, this completes the description of the structure, since nonfood expenditure is obtained as a residual. The nonfarm demand component, however, includes an equation to explicitly estimate nonfood demand. In order to assure consistency with total expenditure projections, a balance equation is added to the equation set and an elasticity expansion parameter calculated to force the balance. Mathematically, the set of equations to be solved is,

$$q_i = q_{10}[f_i(\text{price, income})]^S \quad i = 1, 2, \ldots, \text{number of commodities} \tag{5}$$

$$\text{Total Expenditure} = \textstyle\sum_i P_i q_i \tag{6}$$

The elasticity expansion parameter (S) is constant across all demand equations at any point in time and varies over time. It proportionally changes the value of each elasticity so that the projected total nonfarm consumption expenditure equals the expenditure implied by the commodity-specific demand and price projections. The nominal value of this parameter is one, and its simulated value should remain close to one over time.

After all prices and consumption levels have been calculated consistent with the budget constraint and with the policy-specified price bounds, the emphasis shifts to foreign trade and demand accounting. DEMAND calculates net exports (imports) for each commodity as the surplus (deficit) of domestic production over feed and industrial demand, losses, stock change, and farm and nonfarm food demand. The exogenously projected world prices convert these individual surpluses and deficits into the net agricultural contribution to the balance of payments. In addition, self-sufficiency percentages are computed for each commodity. Finally, this component of DEMAND calculates the daily per capita nutritional intake of protein and calories, by nonfarm and farm populations and by plant and animal sources.

In summary, DEMAND projects total and per capita consumption levels for farm and nonfarm populations, producer and consumer prices, and nutrition and trade variables.

Information Requirements

Several kinds of information are required to operate DEMAND. Behavior and policy parameters determine the relative shapes of the price and consumption responses, while the absolute response levels are determined by the values of the endogenous variables at the beginning of a run (the initial conditions). Exogenous variables, which are determined outside of DEMAND and which can change from one time period to the next, are the driving forces to which the component responds.

Parameters

The parameters of the model can be classified as (1) policy parameters, (2) behavioral parameters, and (3) accounting coefficients, depending on whether or not they characterize public or private actions or express identity relationships, respectively. In DEMAND the *behavioral parameters* characterize the income and price responses of the demand equations. These include the long-run limiting consumption levels, own-price elasticities, substitution proportions, and the relative slopes.

The income response of demand is partially determined by the consumption limits. These are the levels of per capita consumption beyond which additional income will not affect per capita consumption. That is, the income elasticity goes to zero as consumption approaches the limits.

The price response of demand depends on the own-price elasticity, the substitution proportions, and the relative slopes. The own-price elasticity is the percentage change of consumption of a commodity resulting from a one-per-cent change in its own price. The substitution proportion for a given commodity characterizes the quantity change in the consumption of all food commodities as a result of a change in the price of a given commodity. (This is the column sum of the elements of the first matrix in equation (2).) The relative slopes are the per cent of the change in the consumption of one food item following its own price change that is made up by an opposite change in the consumption of another food item. (These are the off-diagonal elements of the first matrix in equation (2).)

Government *policy parameters* in DEMAND include the exchange rate, stock levels, farm price policy, bounds on consumer prices, and nonfarm price or quantity policies. The exchange rate used in DEMAND is the official rate of the Korean won per U.S. dollar. The stock level is the amount of each commodity required to satisfy the desired number of months of consumption held in government household and private inventories at the beginning of the crop year; it may vary among commodities.

The farm price policy parameter specifies whether producer prices are set by government policy or whether they are linked to consumer food prices by marketing margins. If producer prices are set by policy, the projected time path of these prices must also be specified.

The consumer food price bounds are upper and lower limits outside which the domestic food price is not permitted to rise or fall. These bounds are expressed as proportions of the world price or of the consumer price in the previous period, or both.

Corresponding to each policy in the "mutually exclusive" policy set (Table 1)--where the analyst must set either price, per capita consumption, or import levels--is a data set containing the projected time path of that particular variable. In addition, a separate parameter indicates which policy is chosen.

The major *accounting coefficients* in DEMAND express the nutritional content of the food commodities (protein and calorie), convert foods to a polished grain equivalent, and express the margin between farm and consumer prices. The marketing margins show the per cent mark-up between farm and consumer prices. This mark-up may vary among commodities but is a constant proportion through time.

Initial Conditions

The initial condition data for a model are the starting values of the endogenous state variables. In other words, they are the last "real-world" observations before the model begins to work. For DEMAND as a component of KASM, this base-year data is for 1970 in the verification runs and 1974 for projections.

The initial stock levels are the November inventories held by households, government, and at ports in the year prior to the base year; e.g., 1969 or 1973. They exclude stocks held in private and cooperative marketing channels.

The initial levels of per capita consumption are calculated in the model to agree with the food balance data for 1970 or 1974 as reported in KASS Special Report 11 [11]. The national per capita consumption levels are made consistent with the supply available for human consumption and the farm/nonfarm ratios of per capita consumption.

The initial consumer price levels are the base-year retail prices in Seoul. The initial producer prices are the prices received by farmers or unit value of production in the base year. Producer prices in 1969 are used to initialize the lagged prices used in the farm consumption functions.

The income elasticity of demand is not directly observable but must be inferred from other data. The values used in the base year for the model were cross-section estimates adjusted to track the 1970-74 time period.

Variables, some of which had starting values set as initial conditions, differ from the parameters of the model in an important way. The parameters do not change through time, while the variables change from year to year as conditions change over time in the simulation.

Exogenous Variables

The exogenous factors of DEMAND are population, income, food supplies, nonfood prices, and world prices for food imports and exports. Both farm and nonfarm population levels and per capita farm and nonfarm disposable income are demand shifters. They set the overall level of demand.

The domestic supply of food for human consumption is the balance remaining after losses, seed, feed, and industrial demands are subtracted from the harvest and carry-over. Feed, seed, losses and industrial demands are calculated in the production component of KASM (Chapter 11).

The nonfood price index deflates the observed food price changes to remove overall inflationary trends and obtain real price changes. Its value is one in the base year. The world prices for imports and exports are calculated by interpolating projections of international commodity prices derived from the World Bank (IBRD) [3]. Import prices are assumed to be 20 per cent higher than the export prices for similar commodities reflecting a margin for transportation and handling. The assumed margin in the case of rice and barley is 30 per cent. In addition to these purely exogenous variables, lagged endogenous variables also affect the demand relations.

Endogenous Variables

Endogenous variables are calculated inside DEMAND. They may be determined either jointly or in sequence within the component. The component must include all variables which are influenced by and simultaneously influence the endogenous variables contained in it.

The endogenous variables of the component may be either observable or nonobservable in the "real world." Observable variables correspond to data series obtained by direct observation of the real world; e.g., market prices. Nonobservable variables are time-varying parameters of the model and can only be inferred from observed data; e.g., the income elasticity of demand.

The observable variables in DEMAND are consumption, price, nutrition, import/export levels, and the agricultural contribution to the balance of payments. Consumption levels of food are calculated for the farm and nonfarm populations, both on a per capita and total basis. Total and per capita expenditures on food and nonfood items, as well as the physical amounts of food, are also calculated in the model.

The consumer price of food commodities corresponds to the retail price in Seoul, as reported by the Economic Planning Board. The corresponding producer price is either the unit value of production or the national average price received by farmers. The price received by farmers is used for beef, pork, chicken, and eggs.

Nutrition is calculated as the per capita daily consumption of protein and calories. These are separated into those from plant and animal sources and by farm and nonfarm consumers.

The import and export levels are the number of metric tons required or remaining after food, feed, and industrial demands; losses; and stock changes have been subtracted from domestic production and carry-overs. The agricultural contribution to the balance of payments is the accumulated value of these deficits and surpluses.

The nonobservable variables in DEMAND are time-varying parameters in the relationships. These include the income elasticity, the cross-price elasticities of demand and the corresponding partial derivatives, and the elasticity expansion parameter.

Component Testing

DEMAND has been tested continuously in the course of its development. Indeed, successive changes and improvements resulted from those tests.

Early tests examined the price response of changing supplies for various commodities, and results of these tests led to a generalization of the policy options built into DEMAND, particularly the inclusion of price bounds.

Later, significant effort was invested in compiling price and consumption time series and in estimating demand relationships for farm and nonfarm consumers [12]. These data were used to improve the consistency of the initial conditions of the model.

In addition, intensive "manual" tuning of the elasticities and substitution relationships helped the model to track the actual 1971-1974 national average per capita consumption levels, using actual prices and income in that period. For most commodities, good fits were obtained, where the goodness-of-fit for each commodity was measured by the normalized sum of squared errors. Specifically,

$$F_i = \sum_{t=1971}^{1974} \left(\frac{C_{it} - \hat{C}_{it}}{\overline{C}_i} \right)^2 \tag{7}$$

where C_{it} is actual per capita consumption of commodity i at time t, $\hat{C}_{it}$ is simulated consumption and $\overline{C}_i$ is the mean value of the time series; i.e.,

$$\overline{C}_i = \tfrac{1}{4} \sum_{t=1971}^{1974} C_{it} \tag{8}$$

Table 2 shows the results of these tests, where a perfect fit would give a zero value of F.

Table 2. DEMAND Time-Series Tracking of Consumption

Commodity	F*	Commodity	F*
Rice	.013	Tobacco	.309
Barley	.012	Industrial crops	.410
Wheat	.070	Beef	.083
Other grains	.115	Milk	.633
Fruit	.014	Pork	.005
Pulses	.020	Chicken	.011
Vegetables	.025	Eggs	.046
Potatoes	.028	Fish	.058

*Normalized sum of squared errors.

Further Improvement and Extension

In its current form, DEMAND has been shown to be a practical and useful model for projecting future levels of prices, consumption, trade, and nutrition in Korea. This does *not* mean, however, that improvement and extension of its capabilities are not possible or desirable as time and resources permit. This section outlines a number of changes which would improve and increase its capabilities. The farm demand component, government nonprice policy analysis, and the empirical base for the model are suggested for possible extension and improvement.

The farm demand component can be revised on a number of fronts. Three will be mentioned. The method of calculating the nonfood expenditure by farm people can be revised to parallel the method used in the nonfarm sector. The current method calculates nonfood expenditure by subtracting food expenditures from farm income. The revision would involve estimating a nonfood demand equation for farm people and adapting the solution algorithm of the nonfarm component to the farm component.

The nonfood expenditure calculation is part of a more general problem of farm household behavior. The allocation of consumption and investment expenditures in farm households is somewhat more complicated than in nonfarm households and certainly has a significant impact on output in the agricultural sector. Dong Min Kim [4] has developed a preliminary model of the farm household which can guide revisions in this direction.

A third revision for the farm component of DEMAND would be to shift from the subsistence farm assumption to a market-oriented farm assumption.

This would relate the market demand in the farm sector to current consumer prices in addition to (or in place of) lagged producer prices. The farm and nonfarm demands would be added together and, with supply, would jointly determine the market price, rather than the present sequential, noninteractive market mechanism.

The Korean government has pursued a number of policies aimed at affecting food consumption without altering the price structure. These nonprice policies have included riceless days, mixed grains, flour foods (honshik, boonshik), and various other promotional devices. While the effects of these policies have been analyzed as necessary on an ad hoc basis, it is desirable to formalize the analytical capability to address these issues. In this regard, it is important that the kinds of non-price policies that may be employed by the government be foreseen and modeled, perhaps as proportional shifters of the price-income demand curves.

Another area for further investigation is the empirical base for the model. Indeed, this activity could probably expand econometric theory and methodology in addition to improving KASM This work could proceed along a number of lines.

DEMAND has evolved from a constant price elasticity system to a linear substitution system. The next logical step in this evolution would be a totally linear system of demand equations. Methods to estimate the entire system of linear demand equations including an expenditure constraint exist in the literature.[5] Stone's method [7, 8] estimates expenditure as a linear function of commodity prices and income. The expenditure constraint reduces the free parameters in each demand equation to two and results in a singular covariance matrix for the system of equations. However, estimation methods have been developed in spite of this singularity [6].

The primary benefit of such an approach is that the statistically estimated model and the computer simulation model would be of the same structure. Hence, the simulation model would be consistent with the estimation procedure used to derive parameter values from observed data. As a result, there may be less need to adjust the coefficients or results.[6]

A number of nuances in the existing computer model challenge econometric methods of estimation. If the constant price elasticity demand model were retained, it should be reestimated in the same form as the simulation model. A constant elasticity of demand model consistent with an expenditure constraint has been examined by Theil and Barten [1, 2, 9, 10]. The result is a model which is not linear in either the parameters or the price, quantity, or income variables. This could replace the elasticity expansion approach to the budget constraint presently used, since the estimated elasticities in such a model would already constrain total expenditure.

The present income elasticity specification in the computer model is a two-part econometric challenge. The first part of the challenge is to solve the nonlinear partial differential equation[7] it implies. The second part is to statistically estimate the parameters of the closed-form solution. This, like the Theil-Barten demand equations, will be nonlinear in both the parameters and the variables.

FOOTNOTES

[1] The only functional difference between the nonfarm and the farm demand components is an "elasticity expansion" parameter. This changes all nonfarm demand elasticities proportionally to insure that the projected levels of prices and demand agree with the projected total expenditure.

[2] This is the percentage change in, for example, rice consumption for every percentage change in rice price.

[3] These are the percentage changes in, for example, wheat, barley, and potato consumption for each percentage change in rice price.

[4] In mathematical terms, the nonfood cross elasticities are

$\varepsilon_{nf} = -(\sum_j \varepsilon_j + \varepsilon_y)$ for each food commodity, where ε_j is the elasticity with respect to the j^{th} price and ε_y is the income elasticity.

[5] For a survey, see [13]. In particular see [5, 7, 8].

[6] Adjustments reflecting truly unprecedented events are legitimate and required. But a change reflecting "expert opinion" or because "it doesn't look right" should have been specified as prior information; and Bayesian, rather than classical, statistical methods should have been employed to estimate the relations. For example, see [14].

[7] The equation is,

$$(q - T/2)^2 = \frac{(q_0 - T)}{\eta} y\frac{\partial q}{\partial y} + (T/2)^2$$

where q is per capita consumption, y is income, and the parameters are T, the consumption limit; η, the initial income elasticity; and q_0, the initial consumption level. This is derived from the following equation of the models:

$$\varepsilon(t) = \eta(q-t)/(q_0-T)$$

where $\varepsilon(t)$ is the income elasticity at time t; i.e., $\frac{\partial q}{\partial y} \cdot \frac{y}{q}$.

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CHAPTER 13

DATA REQUIREMENTS AND PARAMETER ESTIMATION

Alan R. Thodey

It is well known that the estimates and projections made by a simulation model can only be as good as the data upon which they are based. The Korean Agricultural Sector Model (KASM) is no exception. Are the data required by KASM readily available? If so, are these data accurate, consistent, and timely? This chapter examines these questions, together with some of the items considered in defining commodity groups and in using the available data. The question of whether the model inludes all, but only relevant, data is not considered.

A relatively detailed agricultural sector model, such as KASM, requires an enormous amount of information. Since the model requires that all relationships be explicitly expressed in quantitative terms, almost all of this information must be incorporated in the model as numbers. This is demanding for any agricultural sector, but particularly so in situations where the agricultural data base is incomplete and of limited duration. In fact, in most such situations, developing and operating such a model is difficult, if not impossible. In the case of Korea, the existing data base permitted such a model. This data base was improved markedly in the early 1960s in response to the initiation of economic planning. By the beginning of the Second Five-Year Economic

Development Plan, 1967-71, the coverage, methodology, and collection of agricultural and economic statistics, among others, had been significantly improved. This does not mean, however, that further improvement is neither possible nor desirable.

Type of Data Requirements

The data required by each component of the model generally fall into four categories:

1. Lagged endogenous variables--for the first period of the model, these are the initial conditions (or base values) of the variables to be projected by the model and are based on observations in the real world, where possible. In subsequent periods model output from previous periods is used (together with the initial conditions, if required). These variables may come from the same or some other component

2. Exogenous variables--the initial and projected values of these variables are derived outside the model by various methods and are given to the model as input

3. Technical, institution, and behavioral parameters--these are incorporated in relationships containing the predetermined variables (1 and 2 above) and are used to project the endogenous variables subject to the policy parameters. The initial and projected values of these parameters are generally predetermined, although some may be endogenously determined

4. Policy parameters--the set of policy options is given from outside the model (precise specification resulting from interaction between decision-makers and analysts) and provides the framework for projecting the endogenous variables and parameters

Examples of the four types of data required in each component of KASM are shown in Table 1. For example, the population component uses the population by age, sex, and sector in the previous period as its base for projecting births, deaths, and migration in each period (year). Projected exogenous variables, such as the level of urban unemployment, are used in determining year-to-year variations in these projections.

Table 1. Examples of Types of Data Requirements in KASS Model Components

Component	Predetermined Variables			Technical, Institutional and Behavioral Parameters	Policy Variables and Parameters
	Lagged Endogenous		Exogenous		
	Within Component	Outside Component*			
Population (POPMIG)	Population by age, sex, and sector	Nonagricultural employment	Urban unemployment	Birth rates Death rates Migration rates	Population (birth rate) control Nonagricultural employment of farm population Military manpower
Crop technology change (CHANGE)	Crop yield Input use Land classes	Prices Crop areas Farm income Tree crop age composition	Land development costs Maximum potential land area improvement Private nonfarm capital	Production coefficients Diffusion rates Input demand elasticities Farm consumption investment ratio	Land and water development investment Crop improvement Extension services Price policies (input and output) Agricultural finance policies
Farm Resource allocation and production (FRESAL)	Cropping patterns Herd sizes Capital stock Farm savings	Producer prices Input prices Maximum farm labor Maximum land and water Crop yields	Livestock yields	Resource requirement coefficients Maximum credit ratio Depreciation rates Maximum change coefficients	Agricultural finance policies Feed grain imports (maximum)
Demand-price-trade (DEMAND)	Per capita consumption Producer prices	Population Agricultural supply Agricultural income Nonagricultural income	Target per capita consumption World prices	Income elasticities Own-price elasticities Substitution proportions	Price policies Food consumption policies Exchange rates Foreign trade
National economy (NECON)	Unit profitability Unit costs Gross investment	Nonfood expenditures Agricultural input demand	Labor productivity Nonagricultural exports World prices	Input-output coefficients Price and income elasticities for nonfood items Profit and investment utility elasticities	Public consumption Public investment Price policies Import substitution Tax rates

*Assumes all components are linked. If not linked, then these are exogenous variables.

Also, by varying the nature of the government's population control (family planning) program, it is possible to raise or lower birth rates. In the present version of the component, this must be done by readjusting the behavioral parameters (birth rates), although it could be incorporated directly once the relationship between government programs and birth rates were established.

Commodity Groupings

In the components of the model related to agricultural production, consumption, and trade, 19 agricultural and one nonagricultural commodity groups are distinguished. They are,

1. Rice
2. Barley
3. Wheat
4. Misc. grain
5. Fruit
6. Pulses
7. Vegetables[1]
8. Potatoes
9. Tobacco
10. Forage
11. Silk
12. Industrial crops
13. Beef
14. Milk
15. Pork
16. Chicken
17. Eggs
18. Fish/Seaweed
19. Residual Food
20. Nonagricultural

The nonagricultural group is further divided into subgroups in the national economy component.

The agricultural commodity groups selected represent a compromise between narrow groupings of relatively homogeneous commodities and a manageable number of groups, both in terms of the model and data generation. The major commodities are specified separately, such as rice, barley, and wheat. In addition, the livestock products are specified separately because of their own unique production characteristics. Other commodities are grouped together. For some purposes, additional groupings have been necessary, such as the production of summer, fall, and winter vegetables. Certainly further subdividing fruits, vegetables, potatoes, and industrial crops would be desirable for many purposes. To do so in the model, however, would substantially increase the size and operating cost of the model.

In almost all cases, commodities are measured at the farm level in the same form as specified by the Ministry of Agriculture and Fisheries. These forms are shown in Table 2. Also shown are some of the more important items contained in each commodity group. It should be noted that within groups, commodities are simply aggregated without reference to relative value, nutritive content, or other factors. Hence, apples are considered equal to oranges, as they are to peaches.[2]

Availability and Quality of Data

For projection purposes, the base year used in the model should be the most recent year for which a complete set of data is available. This means that the base-year data in the model should be updated annually. For validation and verification purposes, however, it is desirable to use an earlier base period, so that projections can be compared with reality. The initial (1972) version of the model used 1970 as its base period. The 1975-76 version used this same base period for tracking purposes but updated the base-period data to 1974 for projection purposes. All data relate to a 12-month period.

Data from the mid-1960's exist in Korea on almost all variables included in the model.[3] Population, agricultural, fishing, and mining and manufacturing censuses are conducted periodically; farm and urban household surveys are conducted continually and reported annually;

Table 2. KASS Commodity Groupings: Form and Composition

KASS Commodity Group	Form	Commodities Included
1. Rice	Polished grain equivalent	Nonglutinous Glutinous
2. Barley	Polished grain equivalent	Common Naked
3. Wheat	Grain	Wheat
4. Misc. grain	Grain	Corn Millet Rye Sorghum
5. Fruit	Edible harvested fruit	Apples Grapes Oranges Peaches Pears Persimmons
6. Pulses	Grain	Green Bean Red bean Soy bean
7. Vegetables a. summer b. fall c. winter a/c summer winter	Edible harvested vegetable	a. Cabbage Carrot Eggplant Ginger Muskmelon Parsley Strawberry Watermelon Welson onion b. Chinese cabbage Radish c. Garlic Onion Spinach a/c Cucumber Lettuce Pumpkin Red pepper Tomato
8. Potatoes	Fresh Tuber	Sweet White
9. Tobacco	Green Leaf	Burley Virginia
10. Forage	Fresh (as harvested)	
11. Silk	Raw silk	
12. Industrial crops a. edible fiber b. inedible fiber	As harvested (grain/fruit	a. Perilla Rape Sesame Sunflower b. Castor beab Cotton Hemp Black rush
13. Beef	Fresh meat	
14. Milk	Fluid	
15. Pork	Fresh meat	
17. Eggs	Fresh unshelled	
18. Fish and Seaweed	Fresh (As caught)	Fish Whales Crustaceans Mollusks Other aquatic animals Seaweed
19. Residual food	Fresh meat	Goat Rabbit
	Fresh	Edible offal
	Processed	Animal fat Chemical spices Salt Sugar
	Dried	Cocoa Coffee Tea

producer, wholesale, and consumer prices are monitored and reported; crop area, yield and production, and livestock number and production are estimated annually; and so on. These data generally become available in less than one year. Nevertheless, there are some important data gaps, such as losses associated with harvesting, storing, transporting, and processing; inventories held by the private market and cooperatives; quantity of agricultural commodities consumed by industry and as feed; and conversion factors for agricultural products.

Perhaps more important than the availability of relevant data in Korea is the accuracy and consistency of these data. Most of the agricultural statistics in Korea traditionally originated from estimates by local officials passed through the administrative structure to the Ministry of Agriculture and Fisheries. Such estimates have tended to be biased, often depending on economic and political factors. For example, during the period of forced sales of grain to the government, the planted area was underreported. After these sales were abandoned and following the government's decision to rigidly control fertilizer distribution on the basis of planted area (with grain crops receiving priority), the planted area tended to be overreported. Reported crop yields also appear to have been influenced by various factors, such as the expectation by officials at higher levels that target average yields had been achieved. These types of problems are well recognized; and improved data collection, handling, and analysis methods are being employed. In 1974, for example, the Bureau of Agricultural Statistics established an independent network of province and county offices so that it could collect the required data directly at the farm level.

Table 3. Average Per Capita Rice Consumption Estimated by Various Methods and Sources, 1965-74

Year	Consumer Survey Method			Balance Sheet Method		
	GCS	FHS/UHS		KASS	FB	FAO/K
		Quantity	Expenditures			
	(kg per person per year)					
1965	120.4	119.4	---	124.4	---	130.6
1966	124.2	120.5	---	111.4	---	111.9
1967	133.2	126.7	---	119.9	---	128.7
1968	132.7	118.9	---	113.7	118.3	117.6
1969	127.0	115.7	---	116.1	120.2	113.6
1970	135.9	(130.3)	---	125.4	130.9	131.7
1971	135.2	122.6	---	135.4	140.2	137.8
1972	133.7	112.8	---	120.6	125.1	127.6
1973	128.3	127.0	127.6	116.6	121.1	122.2
1974	126.9	---	---	124.1	128 8	133.6

GSC — Grain Consumption Survey (MAF)--calendar-year basis

FHS/UHS--quantity — Quantity of purchases reported in the Farm and Urban Household Surveys (MAF and EPB/NACF)--calendar-year basis

FHS/UHS--expenditures — Quantity of purchases derived from expenditure reported in the Farm and Urban Household Surveys, estimated using prices received by farmers and Seoul retail prices (MAF/NACF and EPB/EPB)--calendar-year basis

KASS — Korean Agricultural Sector Study--rice-year basis

FB — Food Bureau, MAF--rice-year basis

FAO/K — FAO Korea Association, "Food Balance Sheet," --calendar-year basis

Source: Alan R. Thodey, "Food and Nutrition in Korea, 1965-74," Special Report 11, NAERI-MSU, 1976, Table 4.5 and Appendix 8.

In addition to problems of accuracy, much of the available data appear to fail the test of consistency.[4] For example, the estimates of per capita food consumption derived by different surveys and different mdthods are quite different for most years. This divergence can be seen for rice, for example, in Table 3. Remembering that most effort is probably applied to collecting data on rice, the most important food in Korea, the estimates for other crops are probably even less certain. In part, some of these differences result from differences in the definitions used and in the methodologies employed. For example, the food balance sheet approach is based on estimates of production plus imports less decreases in stocks. The KASS estimate in Table 3 defines production to be harvested production, whereas the Food Bureau uses production standing in the field before harvest (crop-cutting survey estimates). The difference is the adjustment for estimated harvest losses. Similarly, some of the definitions in the farm and urban household surveys are not consistent with each other.

Some of the available data could be used without modification in the model to represent the base-period value of those variables. In other cases, conversion of the existing data into another form was necessary. And finally, substantial manipulation and/or adjustment of some data was required to derive base-period estimates satisfactory for use in the model. For example, obtaining estimates of per capita consumption of the farm and nonfarm populations required that the basic data be changed as necessary to be as accurate and as consistent as possible and that estimates be made of the farm-nonfarm split in total consumption.[5]

Parameter Estimation

The technical, behavioral, and institutional parameters used in the model were derived in various ways. At one extreme, parameters were already available or were estimated as a simple relationship between two variables where the data were readily available. Fitting into this category are relationships between prices, some of the input requirements per unit of output, and savings ratios. At the other extreme, parameters were derived by judgments, based on background estimates and the reasonableness of the resulting projections by the model: most of the elasticities fit into this category. Most parameter estimates fall between these two extremes and are generally based on available Korean data.

The model is generally sensitive to many of the income and price elasticities of demand used in the demand-price-trade component. As a result, the selection of elasticities has received considerable attention. In the first version of the model, the elasticities were mostly judgments based upon the knowledge and intuition of several specialists. More recently, the per capita food consumption estimates for 1965-74 developed for base-line use in the model [3] were used to estimate income and price elasticities of demand [2]. In addition, recent cross-section expenditure data from the farm and urban household surveys were converted into quantity terms, grouped according to the KASS commodity categories, and used for estimating income elasticities of demand [2]. This permitted all of the time-dependent factors to be held constant. With various commodity groupings, data from these same surveys for 1965 to 1974 were used to also estimate both income and price elasticities of demand. Many of the resulting estimates of the price elasticities, particularly the cross-price elasticities, were inconsistent with normal expectations, including the expectation of negative own-price and positive cross-price elasticities of demand. As a result, the relationships between the quantity changes of close substitutes, such as all grains and all meat products, were also analyzed. The model was then adjusted to incorporate matrices of substitution relationships between all grains and all meat products to be used by the model to estimate cross-price elasticities on the basis of the own-price elasticities. This method was adopted because it appeared to be easier to obtain estimates of substitution relationships rather than cross-price elasticities directly.

The actual income and own-price elasticities and substitution proportions used in the model were based on the above analyses but were subsequently adjusted to better reflect expected behavior. These adjustments were mostly based on the judgments of specialists familiar with actual price behavior.

In statistically estimating parameters, three types of errors were often encountered that resulted in the need for the judgmental adjustment of the estimated parameters. First, many of the data contain errors both of accuracy and consistency. Second, relevant variables were omitted from the estimating relationships. This occurred for various reasons: data were not available; insufficient observations (years of data) were available to permit inclusion of additional variables (in most years they were judged of minor relevance), and the relationship was not considered. And third, some of the types and forms of relationships used were possibly wrong; for example, all time series data were converted to logarithmic form.

Projection of Exogenous Variables

As the examples of Table 1 suggest, the model incorporates a substantial number of exogenous variables. These variables must be projected outside the model and then incorporated into the model. Some of these projections came from existing sources, such as projected world food and nonfood prices from the World Bank. Most, however, were judgments based on the available data for Korea and other relevant countries.

The demand-price-trade component includes a projection of per capita consumption beyond the projection period; that is, for some time after 2000. These projections (targets) adjust the income elasticities of demand over time so that they are consistent with expected consumption patterns. They were derived as a "best judgment" by food and nutrition specialists in Korea and provide a reasonable intake of energy and protein. First, present and foreseeable consumption trends were considered; the Japanese experience was considered invaluable in identifying these trends. These were then subjectively adjusted for the response expected from the government as a result of these trends being increasingly realized; for example, meat consumption was reduced substantially below trend levels because of the projected lack of domestic feed supplies and likely policies aimed at reducing consumption. Also, the effect of diminishing marginal utility was considered for all foods. Finally, the projections were adjusted for their nutritive content relative to expected and required nutritional levels. This was an iterative process, with the specialists responding to proposed targets and ultimately coming to a general consensus.[6] Of course, these targets can be expected to change as the underlying assumptions change and as improved data become available.

Another set of projections based on a substantial research effort was made up of those related to land and water development. One such effort involved a linear programming model to identify various optional alternatives.[7] Ultimately, the crop technolgy change component will project land and water development endogenously.

Policy Variables and Parameters

Since the model aims to provide relevant analyses for agricultural sector decisions at the national level, it is necessary to include the major policy options available as variables in the model. The process of identifying the relevant types of policies is an iterative process involving interaction with the decision-makers. This interaction is even more critical in selecting the values to be attached in these policy variables and parameters when alternative policies are being analyzed.

Summary

The model requires a very large amount of data, both for the base period and even the projection period. While most of the relevant data are available in Korea, much of it is of questionable accuracy and consistency. Further, the data in general do not permit very complex or sophisticated estimation techniques to be employed. Hence, a very considerable effort was required to adjust the variable and parameter estimates to be consistent with the best judgment of the specialists.

The process of validating and verifying the data used in the model is a large and continuous task. A model, such as the KASS model, requires a substantial manpower commitment for this purpose. It requires that the variables and parameters be continuously updated as data become available. Ultimately, the quality of the projections is only as good as the data on which they are based.

FOOTNOTES

[1] After the groupings were first identified and used in the model, it became desirable to separate the production of vegetables into summer, fall, and winter vegetables. These three supply activities are then added together for interaction in the demand-price-trade component.

[2] However, for such purposes as estimating base-period prices and average nutritional value, each commodity within the group is weighted according to its base-period quantity.

[3] A summary review of the Korean agricultural data system is provided in [4]. A more detailed description and critical analysis of the Korean agricultural data system is contained in [1].

[4] Data are considered consistent when (1) the same variable is measured in exactly the same way over time, (2) different measures of the same variables are identical, and (3) the sum of various component parts of a variable equal the total derived by an alternative method.

[5] The estimation procedures employed are described in [3].

[6] See Alan R. Thodey [3], Chapter V.

[7] This is reported further in Chapter 15.

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CHAPTER 14

UTILIZATION OF A SYSTEM OF MODELS FOR AGRICULTURAL DECISION ANALYSIS

Michael H. Abkin
Fred A. Mangum, Jr.

Problems and Subjects

The last several chapters have conceptualized and described the Korean Agricultural Sector Model (KASM), a subject-oriented system of models designed for use in agricultural decision analysis in Korea. With respect to agricultural decisions, our focus has been not on the private, agriculture-related decisions made by producers, marketers, and consumers, but rather on the decisions made by public decision-makers concerning national agricultural policies, programs, and projects at the sector and subsector levels. These public decisions help shape the environment within which the private decision-makers act. KASM is intended to contribute to the analysis phase of the public agricultural decision-making process in Korea by providing some information on the likely consequences of alternative courses of action (decisions).

For our purposes, a problem is defined as a situation in which a specific decision has to be made. When faced with such a situation, a decision-maker always uses a model specifically designed to analyze the problem at hand. The nature of this model--a problem-oriented model--can range from a mental image held by the decision-maker to a formal computerized mathematical model. More generally, a problem-oriented model is composed of many kinds of models--mental images, verbal descriptions, paper-and-pencil calculations, and computer programs--all interacting with the decision-maker in arriving at a prescription for action. This fact becomes apparent when one realizes that no single type of model can provide all the analytical information necessary--political, economic, social, logistic, financial, physical--on which to base public decisions relating to agricultural development. Therefore, decision-makers typically draw upon many sources, many models, to analyze specific problems. (See Chapter 1 for a detailed discussion.)

A well-defined set of decisions or problems is called a subject area. A model capable of being used for analysis of such a set of problems is called a subject-matter model. In the context of a specific problem analysis, a formal subject-matter model--such as KASM or relevant parts of it--is combined with other relevant models to form the specific problem-oriented model.

In this chapter, we describe the process whereby KASM, a subject-oriented system of models, can be used in problem analysis. In addition to a description of the process, illustrated with an actual instance of such an application, we discuss the need and tests for credibility and present as an example KASM's use in the process of formulating Korea's Fourth Five-Year Development Plan. Finally, we draw conclusions for model utilization and development. But first, we will summarize KASM as a subject-oriented system of models, its problem set domain, and the decision entry points of its components.

KASM: A Subject-Oriented System of Models

In this section we draw together from the preceding chapters in this part, particularly Chapter 7, a summary of the problem set domain of KASM as a whole and of each of its component parts. Included is a discussion of the decision entry points where model-users--i.e., analysts and decision-makers--may interact with KASM to make assumptions related to particular problem analyses.

Problem Set Domain

The problem set domain of a subject-matter model is the set of problems it is designed to address. The problem set domain of KASM is a subset of the set of problems facing Korean public decision-makers at the national level who are concerned with formulating medium-term to long-term (5- to 25-year) plans, policies, programs, and projects for Korea's agricultural sector and subsectors.

Figure 1 shows the problem set domain of KASM as a proper subset of the set of problems with which Korea's national, public, agricultural decision-makers deal. Excluded from the inner circle in Figure 1, but included in the larger one, are, for example, problems of a seasonal and short-run nature (such as those related to the government grain management program addressed by the model described in Part III of this book); administrative and logistical problems related to public regulation, guidance, and administration of the agricultural sector; problems of the sectors which process and market agricultural products and inputs; and problems pertaining to specific localities or regions or to differences among them.

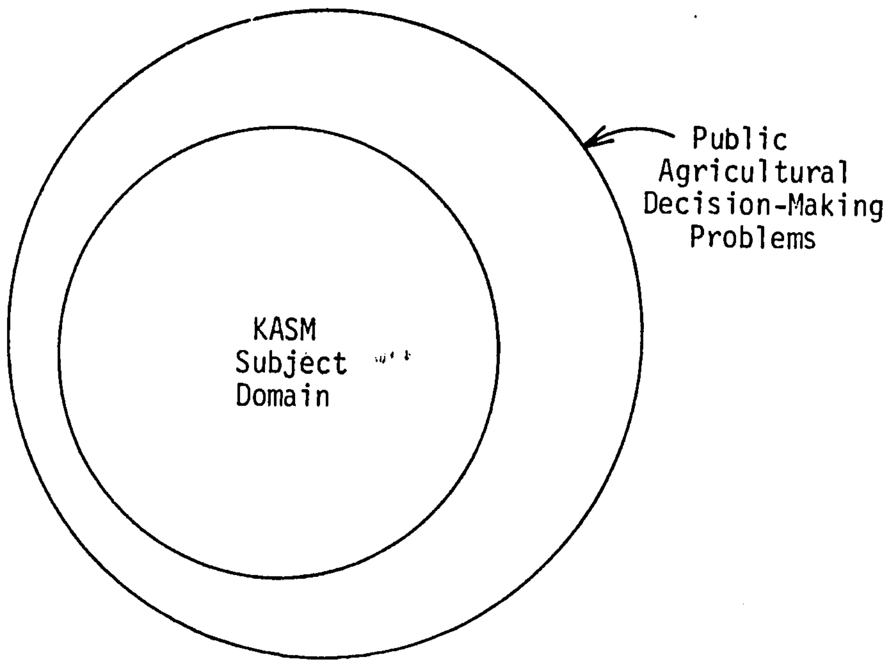

Figure 1. The Subject Domain of KASM Relative to Public Agricultural Decision-Making Problems: Totally Relevant

The five components of KASM (see Chapter 7, Figure 2) each carve out a portion of the subject domain corresponding to one of the five essential aspects of any agricultural sector analysis.

1. The population and migration component (Chapter 8) projects farm and nonfarm populations and the agricultural labor force

2. The national economy component (Chapter 9) models the important feedback linkages between agriculture and the rest of the economy

3. The demand-price-trade component (Chapter 12) projects consumption and nutrition in farm and nonfarm households, as well as producer and consumer prices and agricultural foreign trade

4. The resource allocation component (Chapter 11) allocates land, labor, and capital to the various crop and livestock commodities and to machinery investment, consistent with labor constraints supplied by the population and migration component and with the level of agricultural technology

5. It is the all-important technological development of agriculture that is projected in the technology change component (Chapter 10) which determines crop yield levels; application rates of fertilizer, chemical, labor, and other inputs; and the quantity and quality of various categories of land

Defining a problem, as we have, as a situation in which a decision has to be made, it is clear that the set of problems facing national, public, agricultural decision-makers (represented by the larger circle in Figure 1) is dynamic and ever changing. Problems come, go, and change as Korea itself--including the values and goals of its people--and the world around it evolve over time. If the subject domain of KASM and, therefore, KASM itself remain static in the face of this dynamism, a situation such as that depicted in Figure 2 can and will arise: where part or all of KASM (lying outside the larger circle) is irrelevant or wrong and, thus, is useless to Korean agricultural decision-makers. It is doubtless a fact of life that, because of observation errors and time

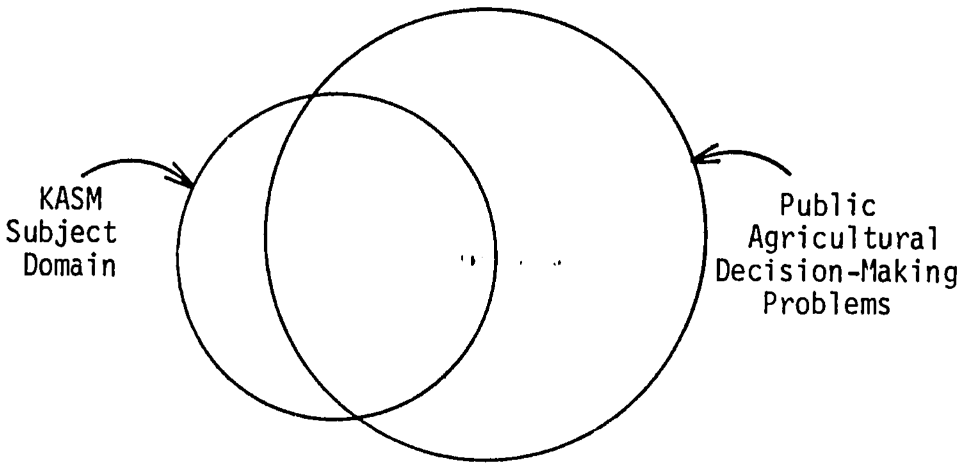

Figure 2. The Subject Domain of KASM Relative to Pub'ic Agricultural Decision-Making Problems: Partially Irrelevant

lags involved in, first, recognizing and identifying changes in the problem set (the larger circle) and, then, in defining and accomplishing modifications in the models (the smaller circle), a portion of KASM will always be irrelevant. Therefore, it is the responsibility of the investigative and analytical capacities maintaining and using KASM to set priorities and work continuously to keep small and relatively unimportant that portion of the smaller circle which is not overlapped by the larger circle.

Even if we assume the ideal situation of Figure 1, there are relevant problems, as we saw above, which lie outside the KASM problem set domain. In such cases, other formal models, such as the Grain Management Program model discussed in Part III, and/or informal models are used in problem-solving analysis. Furthermore, aspects even of problems within the purview of one or more of the KASM components must be analyzed with information from other formal and/or informal models supplementing information from KASM. Such a combination of analytical information sources which can prescribe viable problem solutions is a problem-oriented model.

System of Models

Each component of KASM is a model of one of five subsystems of the agricultural sector--population, national economy, consumption and foreign trade, resource allocation, and technology change. Each of these models may be used alone or in combination with one or more of the others, depending on the requirements of the particular analysis to be done. In many cases, a partial analysis is not only sufficient for the problem at hand but may also be necessary in order to limit the range of options to be tested, the complexity of interactions, and the volume of output to be analyzed.

In actual KASM applications a key factor in its usefulness and, hence, credibility is its comprehensibility. Often, at lower decision-making levels, not only are partial analyses sufficient, but more comprehensive analyses would be confusing and, hence, infeasible, given the partial view of the world institutionally mandated at those levels.

Even the use of KASM for partial analysis, however, admits elements of a more comprehensive view by the very nature of KASM as a *system* of models. Even if only one or two of its components is used in a particular application, a look at Figure 2 in Chapter 7 will immediately identify which of its inputs come from which other components of the system and which of its outputs affect which other components. In addition, considering the component as part of a larger system will help insure consistency in defining and interpreting input and output data.

Of course, higher decision-making levels require more comprehensive analyses, in which case more or all of KASM can be used. Viewing and using KASM as a system of models greatly increase its flexibility and usefulness in various kinds of decision analyses.

Decision Entry Points

A decision entry point is a place in the model where a user--i.e., an analyst or a decision-maker--may make a specific assumption relating to a particular decision analysis. Flexibility is provided in the use of KASM through the selection of components to be used. Far greater flexibility and versatility can be obtained, however, through the ingenuity and creativity of the user himself. A great many decision entry points are explicitly built into the KASM components. In addition, however, a great many others are implicit in the constraints, structural assumptions, and parameter values--any of which may be changed by the user to reflect alternative decisions. Through user ingenuity and creativity, combined with technical familiarity with KASM and the Korean agricultural sector, the number of decision applications or combinations of explicit and implicit decision entry points can be innumerable. Rather than trying to list the decision entry points of each KASM component, many of which have already been described in preceding chapters, illustrations of their use are provided in the next two sections and in the following chapter.

Use of KASM in Interactive Problem-Solving Analysis

Chapter 1 describes the decision-making process as highly iterative and interactive and as composed of six functions (Figure 7, Chapter 1). These functions are problem definition, observation, analysis-synthesis, decision, action, and responsibility-bearing.

Iteration takes place throughout the process and is continuous over time in that the evaluation of the consequences of implementing one decision can indicate resulting problems which also require action on the part of decision-makers. Interaction is also an essential and integral characteristic of the decision-making process. Decision-makers do not act in a vacuum. They of necessity interact with executives responsible for carrying out their decisions, with affected parties who provide feedback for evaluating decision consequences and for identifying new problem situations as they arise, and with investigators and analysts responsible for gathering information and analyzing the possible consequences of alternative courses of action. In using KASM for decision analysis, close interaction between investigators and decision-makers is of key importance. In applications of the model to date, this interaction has proved invaluable not only for defining the decision runs to be made and interpreting the results but also in improving model structure and data input.

It is in the analysis-synthesis function of the decision-making process that KASM makes its direct contribution, along with other formal and informal models, as part of a problem-oriented model. Beyond that, through the interactive iterations inherent in the process, the model also provides information for modifying and refining the problem definition, which gives guidelines for data collection.

The remainder of this section discusses how KASM is used as part of a problem-oriented model for problem-solving analysis. For illustrative purposes, brief reference is made to the land and water development analysis reported in more detail in the next chapter.

Problem Definition

It is very important for the analyst to view the decision-making process from the perspective of the decision-maker. Decision-makers perceive unsatisfactory conditions in the portion of the real world related to their office (the larger circle in Figure 1) and are faced with having to decide on a course of action to improve the perceived situation. Any use of KASM in the analysis of such problems, indeed the decision of whether and how KASM should be used, must be based on the analytical requirements of the specific problem. That is, the use of any given model for decision analysis should depend on the problem definition, not vice versa.

The problem definition, then, starts with the recognition that there is a real-world situation to be improved. In our land and water development illustration, the situation is that Korea is a land-short country trying to provide an adequate diet for its growing population; while at the same time, for economic and national security reasons, it is trying to reduce foreign exchange costs of food imports. As Korea prepares its Fourth Five-Year Economic Development Plan for 1977-1981, important questions arise concerning investment priorities. Given the investment requirements of other sectors of society, what mix of programs in agriculture will best insure an adequate diet and achieve self-sufficiency in the major food staples at the lowest possible investment cost? What will be the effect on food prices and, hence, inflation and farm income?

These questions lead naturally to the next steps in the definition of the problem: selection of performance criteria and identification of decision instruments. What measures of the real world should be used to evaluate the consequences of decisions taken to improve the situation? What decision-making options are available? In our illustrative situation, through interaction with decision-makers in the Ministry of Agriculture and Fisheries (MAF) and in its Agricultural Development Corporation (ADC is responsible for carrying out land and water development projects in Korea), it was decided to analyze the effects on food production, nutrition, and agricultural imports and exports and foreign exchange requirements of alternative levels and patterns of investment in various land and water development (L&WD) programs.[1]

Although the immediate decisions to be made were in the context of the 1977-1981 Fourth Five-Year Plan, the full potential of many L&WD programs take many years to be realized. Therefore, it was decided to look at the 25-year period to 2001.

Decision Analysis

In the analysis stage, a problem-oriented model is defined, put together, and used to project the likely consequences of alternative courses of action. In defining and constructing the problem-oriented model, a combination of art and science is required of the analysts, as described in Chapter 3. The analyst must know what formal models are available which can provide information required to analyze the problem at hand. The art is in recognizing where and how a formal model, such as KASM, can be used. Whether KASM, in whole or in part, can be used in a particular problem-solving analysis depends to a large extent on the creativity and ingenuity, as well as the technical competence, of the analyst in making special assumptions, changing the model structure, and generally molding the model to fit the requirements of the problem definition. This includes molding it to fit into the larger structure of the problem-oriented model, which also incorporates other formal models to provide other kinds of information beyond the scope of KASM. Where formal models do not exist or cannot be specially built, informal components (mental, verbal, diagrammatic, etc.) are used to round out the problem-oriented model.

The problem-oriented model used in the L&WD analysis was composed of KASM components, another formal model (a polyperiod linear program) specifically built for this analysis, and informal components which made exogenous projections required as inputs to the formal, computerized components and which provided other information for the analysis. The KASM components used were the demand, resource allocation and production, population, and accounting components. In place of the technology change component, which was still in a preliminary testing stage at the time of the L&WD analysis, the polyperiod LP was used to project the quality and quantity of the land base resulting from investments in the various L&WD programs and the yield effect of those programs. Basic yield projections, depending on biological improvements, and input application rates were projected informally, based on information from Korean crop researchers and government officials.

KASM was not taken as a given, fixed model when used in the L&WD analysis. Rather, it was changed wherever the analysts felt a change was necessary to meet the requirements of the problem-oriented model. Specifically, price assumptions were changed in the demand component for barley and wheat; some constraint equations in the resource allocation LP were dropped and replaced with others, and special assumptions were made limiting the future expansion of land in nongrain crops; and the definitions of some accounting variables, particularly self-sufficiency percentages, were changed

Once the problem-oriented model has been defined and constructed, an experimental design process specifies the alternative decision assumptions to be investigated with the model and the primary performance variables to be observed. In the L&WD analysis, the alternative decisions were in terms of investment budgets to be spread over time and specific programs. The polyperiod LP then determined for each budget level the optimum distribution over these two dimensions and the resulting land base and yield levels, which were in turn provided as input to KASM.

It is very important to preselect the output variables of primary interest. A simulation model such as KASM can generate a great quantity of information about a large number of variables. Unless the analysts restrict themselves to only those measures of performance most relevant to the analysis, they and particularly the decision-makers will only be confused by the mass of data. More in-depth study of other, secondary model outputs may be necessary, however, to explain unexpected or questionable results.

Testing and use of the problem-oriented model go hand in hand. Each decision run of the model is also a test, and tests can be made on the decision runs, particularly sensitivity tests where the sensitivity of decision consequences to data values or exogenous inputs is investigated. The problem-oriented model is tested in the course of its use and with respect to the prescriptions arising out of its interaction with analysts and decision-makers. The four tests of credibility applied to the model are discussed in the next section.

Analysis of the results of the decision runs, with the interaction of analysts and decision-makers, invariably leads to further iterations respecifying the experimental design, modifying the model, and even revising the problem definition. One example of many such instances in the L&WD analysis occurred when high officials in the Ministry of Agriculture and Fisheries questioned the self-sufficiency projections. Investigation revealed that KASM did not define self-sufficiency in the same way as did MAF, and therefore its definition in KASM was changed.

These iterative interactions among the model, analysts, and decision-makers, as well as with executives and affected parties, ultimately converge on prescriptions for decision. The L&WD analysis provided information which MAF used to back up its negotiations with the Economic Planning Board for L&WD investment capital in the Fourth Five-Year Plan.

Credibility

Throughout the process of defining, constructing, and using a problem-oriented model, the model is continually tested for credibility and modified and refined as necessary until sufficient credibility is achieved with decision-makers for its information to be used in decision-making. Of key importance with respect to a problem-oriented model is credibility in the eyes of decision-makers, and a necessary but insufficient condition for that is credibility in the eyes of the analysts.

As discussed in Chapter 1, there are four essential tests a problem-oriented model must pass for decision-making credibility. These tests are (to recapitulate briefly from Chapter 1),

1. Coherence--where the model is checked for internal logical consistency, abstracted from its real-world referent

2. Correspondence--where the behavior and structure of the model of its real-world referent. Structure is included because it is not enough that a model be able to project; it should also explain past and projected behavior in terms of accounting and dynamic causal relationships. Time-series tracking, sensitivity tests, and decision runs all provide information for correspondence testing

3. Clarity--where the model must be not only unambiguous (which it is if it passes the coherence test) but also comprehensible to decision-makers and analysts alike. Understanding is essential for credibility

4. Workability--where credibility in the problem-oriented model also depends on how well its prescriptions work out when implemented in the real world

KASM and its components have been subjected to each of the four tests. The components have been tested individually and in combination, as reported in the preceding chapters. Coherence tests take place as part of the debugging process of individual components. Correspondence testing of KASM is an iterative process wherein components are tested individually and in various combinations against knowledge of the real-world referent and then are retested continually as new knowledge is gained. Results of time-series tracking and sensitivity tests are reported in earlier chapters.

The clarity and workability of KASM receive their biggest test whenever the models are used for decision analysis. Korean decision-makers and investigators understand the models more and more each time they use them. Similarly, the models become easier to use and interpret as familiarity increases. Workability tests are passed as decisions are implemented with positive results. Positive feedback from these tests of credibility were clearly observed in the course of the analyses reported in this chapter and the next.

KASM and Analysis for the Fourth Five-Year Plan

Utilization of KASM for Ministry decision-making builds upon demonstrated effectiveness in dealing with an existing task. Examples are available of both. However, emphasis here is on the utilization of the models to solve particular decision problems related to formulation of the Fourth Five-Year Plan. While the discussion here is brief, Chapter 15 examines more closely the use of KASM in land and water development analysis.

The setting within which this planning activity occurs is conducive to model application. Three needs are uppermost in the minds of those developing the plan: (1) the time frame imposed upon them, (2) the volume of statistical data that must be considered in both a retrospective and a projective sense, and (3) the consistency that should bind different segments of the plan into a cohesive whole. In all three cases, a generalized simulation model, already in place, holds considerable promise for those charged with actual plan development.

Therefore, as the five-year plan was being developed, it was natural for those in the Ministry to turn to use of KASM for analytical assistance. Fortunately, there was sufficient flexibility that the existing models could be used as already programmed, coefficients could be changed to reflect alternative growth assumptions, or individual components of KASM could be used as needed for particular analyses.

Livestock Planning

Working relationships had earlier been established with MAF officials responsible for livestock planning, and a rudimentary, specialized model had already been used in making mid-period projections during the Third Five-Year Plan period. Working relationships and model appreciation had been further kindled by seminars within the Ministry and frequent contacts between MAF Livestock Bureau personnel, NAERI/KASS, and KAPP. Thus, once the outlines of the fourth plan became known, a request for assistance with the analysis quickly followed from the Livestock Bureau.

The overriding livestock policy objective defined by MAF was to reduce imports of feed grains as a way of conserving scarce foreign exchange. Subsidiary and conflicting objectives were to meet consumer demands for livestock and poultry products and to do so without undue increases in consumer prices. Additional information was sought on the specific effects of alternative techniques for restraining growth--taxes on imported feed stuffs, taxes on livestock *per se*, or other disincentives.

To accomplish the analysis, an informal working group was established, composed of members of the Livestock Bureau, NAERI/KASS, and KAPP. Interchange followed on objectives, on alternative assumptions needed for the analysis, and on input-output coefficients and prices. The exchange was beneficial to both modelers and decision-makers: data requirements and constraining growth assumptions of the modeling effort forced Ministry people to rethink programs for feasibility and consistency and forced the model to be adapted to more realistically meet policy needs. An additional bonus for all future analysis was the opportunity to improve and update the data and structural assumptions for the model.

Repeated interactions led to a livestock program that met the needs of the Ministry. Although the initial request from the Ministry was for only one set of projections, further discussion led to the inclusion of several alternatives. The final results included a base run that was approximately the natural growth rate without policy interventions and two alternatives that exogenously restricted the rate of growth of swine and poultry, the major feed grain consumers. Impacts were estimated for (1) livestock and poultry numbers;(2) real consumer prices for meat, milk, and eggs; (3) per capita consumption of these commodities; and (4) total feed requirements for the livestock sector (Table 1).

The alternatives thus analyzed and refined by discussions with the Livestock Bureau became the basis for policy decisions in the Fourth Five-Year Plan. MAF was able to choose a target plan that achieved the directive of reduced growth in feed grain imports with minimum disruption of the consumer market for meats. At the request of the Livestock Bureau, later analyses will be conducted on specific programs to achieve those targets.

Population Planning

Crucial to any national planning activity are reliable estimates of total population growth and its characteristics. Early in the KASM work, a cohort-survival population model was developed (Chapter 8) to project total, farm, and nonfarm population; off-farm migration rates; agricultural labor supply; and certain population and labor force characteristics. Projections from this component are utilized in KASM as the basis for food demand and for the availability of manpower for agriculture.

In early discussions of the MAF Fourth Five-Year Plan, a decision was necessary to use population projections of the MAF Statistics Bureau, KASM, or for the Ministry to generate others. After due consideration

Table 1A. Limiting Feed Grain Imports by Restricting Hog and Poultry Growth: Impact on Livestock Numbers*

	Year	Base	Alternative I	Alternative II
Dairy Cattle (1,000 head)	1975	89.442 (100)	89.442 (100)	89.442 (100)
	1981	257.900 (100)	257.900 (100)	257.900 (100)
	1986	632.219 (100)	632.219 (100)	632.219 (100)
Percentage of Growth		19.5 (100)	19.5 (100)	19.5 (100)
Korean Cattle (million head)	1975	1.798 (100)	1.798 (100)	1.798 (100)
	1981	2.311 (100)	2.313 (100.1)	2.312 (100)
	1986	1.111 (100)	1.112 (100.2)	1.111 (100)
Percentage of Growth		-4.3 (100)	-4.3 (100)	-4.3 (100)
Hogs (million head)	1975	1.303 (100)	1.303 (100)	1.303 (100)
	1981	1.827 (100)	1.578 (86.4)	1.706 (93.4)
	1986	2.422 (100)	1.742 (71.9)	2.075 (85.7)
Percentage of Growth		5.8 (100)	2.7 (46.6)	4.3 (74.1)
Layers (million head)	1975	32.729 (100)	32.729 (100)	32.729 (100)
	1981	42.862 (100)	33.584 (78.4)	37.997 (88.6)
	1986	54.044 (100)	33.178 (61.4)	42.471 (78.6)
Percentage of Growth		4.7 (100)	0.1 (2.1)	2.4 (51.1)
Broilers (million head)	1975	60.946 (100)	60.946 (100)	60.946 (100)
	1981	78.988 (100)	63.384 (80.2)	71.713 (90.8)
	1986	98.434 (100)	63.384 (64.4)	81.137 (82.4)
Percentage of Growth		4.5 (100)	0.4 (8.9)	2.6 (57.8)

*Figures in parentheses are relative to base = 100.

Table 1B. Limiting Feed Grain Imports by Restricting Hog and Poultry Growth: Impact on Real* Consumer Prices**

	Year	Base	Alternative I	Alternative II
Beef[1] (₩/kg)	1975	913 (100)	913 (100)	913 (100)
	1981	1,000 (100)	1,008 (100.8)	1,004 (100.4)
	1986	1,084 (100	1,084 (100)	1,084 (100)
Pork (₩/kg)	1975	464 (100)	464 (100)	464 (100)
	1981	537 (100)	613 (114.2)	568 (105.8)
	1986	589 (100)	888 (150.8)	708 (120.2)
Chicken Meat (₩/kg)	1975	323 (100)	323 (100)	323 (100)
	1981	406 (100)	498 (122.7)	446 (109.9)
	1986	479 (100)	848 (177.0)	623 (130.1)
Milk[1] (₩/kg)	1975	127 (100)	127 (100)	127 (100)
	1981	118 (100)	118 (100)	118 (100)
	1986	114 (100)	114 (100)	114 (100)
Eggs (₩/10 eggs)	1975	169 (100)	169 (100)	169 (100)
	1981	188 (100)	266 (141.5)	225 (119.7)
	1986	164 (100)	394 (240.2)	261 (159.1)

*In 1970 constant won.
**Figures in parentheses are relative to base = 100.

[1] Little or no difference between runs, due to assumed constraints on price changes.

Table 1C. Limiting Feed Grain Imports by Restricting Hog and Poultry Growth: Impact on Per Capita Consumption*

	Year	Base	Alternative I	Alternative II
Beef (kg/cap)	1975	1.9 (100)	1.9 (100)	1.9 (100)
	1981	3.0 (100)	3.1 (103.3)	3.1 (103.3)
	1986	3.3 (100)	3.6 (109.1)	3.4 (103.0)
Pork (kg/cap)	1975	3.0 (100)	3.0 (100)	3.0 (100)
	1981	4.1 (100)	3.7 (90.2)	3.9 (95.1)
	1986	5.0 (100)	3.8 (76.0)	4.5 (90.0)
Chicken Meat (kg/cap)	1975	1.6 (100)	1.6 (100)	1.6 (100)
	1981	1.9 (100)	1.5 (78.9)	1.7 (89.5)
	1986	2.3 (100)	1.4 (60.9)	1.8 (78.3)
Fish (kg/cap)	1975	25.4 (100)	25.4 (100)	25.4 (100)
	1981	30.2 (100)	30.3 (100.3)	30.2 (100)
	1986	36.6 (100)	36.9 (100.8)	36.7 (100.3)
Milk (kg/cap)	1975	4.5 (100)	4.5 (100)	4.5 (100)
	1981[1]	12.5 (100)	12.5 (100)	12.5 (100)
	1986	17.7 (100)	18.0 (101.7)	17.8 (100.6)
Eggs (kg/cap)	1975	4.7 (100)	4.7 (100)	4.7 (100)
	1981	6.2 (100)	4.9 (79.0)	5.5 (88.7)
	1986	8.1 (100)	5.0 (61.7)	6.3 (77.8)

*Figures in parentheses are relative to base = 100.

[1] Slight changes between runs due to income effects.

Table 1D. Limiting Feed Grain Imports by Restricting Hog and Poultry Growth: Impact on Feed Requirements*

	Year	Base	Alternative I	Alternative II
Total Grain (1,000 MT)	1975	737 (100)	737 (100)	737 (100)
	1981	1,179 (100)	1,027 (87.1)	1,102 (93.5)
	1986	1,583 (100)	1,218 (76.9)	1,388 (57.7)
Total Bran (1,000 MT)	1975	1,874 (100)	1,874 (100)	1,874 (100)
	1981	3,217 (100)	2,953 (91.8)	3,085 (95.9)
	1986	3,305 (100)	2,620 (81.4)	2,946 (91.6)

*Figures in parentheses are relative to base = 100.

and a discussion at a seminar attended by representatives of all the bureaus and non-Ministry advisors, the KASM projections were chosen. The rationale was that the underlying theory and assumptions of KASM more closely resembled reality than did those of other available projections and would be better than any others that could be produced on short notice by the Ministry.

Accepting these projections essentially meant that farm and nonfarm food consumption projections in the Plan would be a function of KASM population projections. Further, farm labor force estimates from the model would underlie planning for mechanization and wage rates in the farm sector.

In this case, anticipation of a planning need, having a model on hand capable of generating information to fill that need, and user confidence in the results led to a direct contribution to a vital Ministry program. Moreover, acceptance of the models and wider utilization came with favorable experiences by those in middle-management positions.

Foreign Trade

A third example of use of KASM in analysis for the Fourth Five-Year Plan was in assessing the export potential of Korean agricultural commodities. In 1974 a MAF committee was assigned the task of determining which commodities might best be developed for export, to where, and in what quantities. Having some knowledge of the foreign trade component, a request for KASM assistance followed.

The demand-price-foreign trade component utilizes a set of demand equations to estimate domestic consumption and, when linked with information from the resource allocation and production component, provides estimates of an exportable surplus and/or import requirements. Commodity prices serve to link (1) domestic demand and supply and (2) the domestic agricultural sector with the world economy.

Addressing the problem posed in the Fourth Five-Year Plan required projections of world supply prices for comparison with projected Korean supply prices. Lower domestic prices over the upcoming Five-Year Plan indicated an advantage and export potential for certain commodities. Information was provided under the assumption of constant real 1974 prices and alternative relative changes from 1974. The 19 commodity groupings of the model proved a handicap, since export planning was in terms of individual commodities. Model results did provide indications, however, for the major commodities and for groupings of others. Basically, the information provided served in this instance as a check and to confirm conclusions already formed by the committee.

Grain Consumption

In the early 1970s, the Korean government strove to reduce rice consumption in favor of barley and wheat in order to reduce foreign exchange costs of grain imports, rice being the most expensive of the three grains on the world market. Measures used included increased government involvement in grain markets, high rice prices, wheat flour subsidies, a dual price system for barley, requiring government rice to be sold mixed with barley, enforcing riceless days in public eating establishments, decreasing the milling rate on rice, etc. Other, sometimes competing, objectives of these measures were to increase farm income, to encourage rice and barley production, to hold down inflation, and to reduce deficits in government grain management accounts.

As work on the Fourth Five-Year Plan got underway in 1975, however, success of the above policies (as well as crop improvement research and extension programs) gave Korea a sense of security that rice and barley self-sufficiency had been attained, with expectations of surpluses in those two grains over the next plan period (1977-1981). The questions now were, what grain consumption patterns could be expected over the plan period and what could the government do now to encourage consumption of rice over wheat, the only food grain expected to be imported (apart from pulses, which are also considered a food grain in Korea)?

Several runs were made with the KASM demand model looking at alternative projected price patterns for rice, barley, and wheat. The analysis indicated that keeping real rice prices constant, phasing out the dual price for barley, and removing the wheat subsidy could result in increased rice consumption, reduced wheat consumption, and limited surpluses of rice and barley.

The Korean government now has removed the wheat flour subsidy, is releasing more and more pure rice (not mixed), and is considering changing the dual price system on barley. While it is impossible to discern what direct influence, if any, the KASM results have had on these decisions, the simulation results at least provided strong confirmation of information coming from other sources.

Conclusions

From the foregoing discussion in this and preceding chapters, we can draw conclusions concerning (1) utilization of subject-oriented models in general and of KASM in particular and (2) areas for further development of KASM and its theoretical foundations.

Utilization

First and foremost, any formal model should be used with great caution, and KASM is no exception. KASM can be a powerful analytical tool for public agricultural decision-making in Korea, where many more complex decision options can be investigated more reliably than could be done with informal or simpler formal models. Nevertheless, erroneous conclusions can easily be drawn from simulation results unless analysts and decision-makers alike take care to understand, by tracing through the model's data and causal structure, what gives rise to those results. Wrong decisions can be made based on wrong explanations of projected responses to alternative decision assumptions.

Furthermore, KASM or any single model, formal or informal, must not be relied upon as the sole source of information for complex public decision-making. No single model can possibly provide all the information necessary--economic, social, political, military, administrative, short-term, long-term, normative, nonnormative, etc. This is equivalent to saying that every problem-oriented model for public agricultural decision analysis will of necessity be composed of multiple formal and informal models.

Fortunately, the decision-making system in the Korean Ministry of Agriculture and Fisheries reduces the chances of making these errors--but it does not eliminate them. Middle-level officials of MAF insist on fully understanding the basis of analyses providing information to their decision-making. In this way they prepare themselves to be able to answer any questions their superiors may ask when proposed plans and programs are presented for approval. Similarly, higher-level officials need to be well versed in the analytical basis of decisions (and therefore ask the questions of lower-level officials) in order to back up their negotiations with other ministries for funding and cooperation. These demands of the decision-makers at all levels of the Ministry place a great responsibility on the modelers and analysts to find ways to explain the models and interpret their results in terms decision-makers can understand--essential if the models are to pass the clarity test for credibility.

Another conclusion we can make regarding utilization of KASM is that it can be either a very flexible system of models applicable to a very wide range of decision analyses or a rigid, specialized model of limited application. Which it is depends not only on the technical knowledge of the analysts with respect to the model, the Korean agricultural sector, and the problem-solving needs of decision-makers. Also important in determining the flexibility of the model and, hence, its utility is imagination and ingenuity on the part of the analysts in artfully selecting and linking components, making special assumptions, and changing data to suit the needs of a particular analysis.

Finally, we must emphasize two characteristics of the model outputs and utilization. First, it is much more useful and valid to compare results of alternative decision runs with each other and with a base run than to look at the absolute projections of any one run. KASM, designed for medium- to long-term projections and analysis, and using sometimes questionable data, cannot and should not be relied upon as a forecasting model. However, a great deal of useful information can be obtained on the likely *relative* consequences of following alternative courses of action.

Second, whenever more than one KASM component is run together, behavioral consistency is incurred among the various subsectors included. In addition, any inconsistencies among policies and programs particular to the various sectors will show up in model outputs in more comprehensive analyses. Thus, although KASM components can be run singly for analysis of decisions at lower levels in the Ministry particular to one subsector or another, combining components for higher-level decision analyses will indicate the significant indirect effects of government actions taken in one subsector on another.

Development

Several conclusions can be drawn relative to further development of the KASS system of models. Most important is the general responsibility of the modelers and analysts maintaining and using KASM for decision analysis to keep abreast of changes in the problem set relevant to Korea's public agricultural decision-makers (the larger circle in Figure 2) so that KASM itself can be modified to keep the portion of its subject domain lying outside that relevant problem set (as in Figure 2) as small and unimportant as possible. This requirement emphasizes the importance of close cooperation and interaction between Korean analysts and decision-makers not only for utilization of the models for decision analysis but also for continual model development.

Specific development areas can be identified at present in addition to the improvements in existing components indicated in the preceding chapters.

1. Recently, MAF has been giving increasing attention to the marketing of agricultural inputs and products. High losses in the 1975 rice crop in some areas of the country were attributed to untimely and inadequate distributions of pesticides to insect-infested areas. On the product side, increased consideration is being given to marketing improvements to curb price rises and reduce commodity losses. In addition, questions are being raised about the effect on production patterns of the transportation and marketing opportunities opening up with the expansion of the highway system into rural areas. Currently, KASM touches product marketing only with price margins and loss rates and input marketing not at all. The marketing of agricultural inputs and products appears to be a fruitful area for further modeling.

2. As useful as KASM was for the livestock analysis for the Fourth Five-Year Plan, it became apparent that its handling of the livestock subsector as part of the resource allocation RLP was inadequate, both (1) as a representation of private sector sales, feeding, and investment decisions and (2) in its exclusion of many of the important government policy instruments influencing the livestock/feed subsector. Preliminary conceptualization has begun in Korea of a set of livestock models, drawing on experiences elsewhere [4, 5] which would incorporate demographic characteristics, investment decisions, sales rates, feeding rates, and the effect of feed prices and supplies. Such models should

also include government credit and subsidy programs, feed and price policies, and pasture improvement programs.

3. Any model is based on the state of the theoretical and methodological art. Advances in investment/disinvestment/user cost theory [1] will contribute greatly to the ability of KASM to simulate agrarian change, capital formation, and growth in the agricultural sector. Some of the most important issues facing Korean public agricultural decision-makers are related to investment, and KASM is currently inadequate to address many of them.

4. KASM has several aggregation error problems. One of the most important is in the resource allocation and production component, where local and regional differences in resource endowments, access to markets, and commodity specialization are obliterated in a national objective function and a national aggregation. The model was originally designed for three regions [6] but was later aggregated due to the difficulty of obtaining regional data and to reduce the costs of model development in other, higher priority areas. At some point it may be useful to consider generalization of the model to flexibly handle disaggregation, not only in the spatial dimension but also by income class in the farm and non-farm sectors, and to facilitate redefinition of the current commodity groupings and the national economy sector aggregations.

5. Flexible disaggregations such as suggested above would put great demands on the data system supplying the model. A long-run development objective should be to design and implement a data management system which would transform data from the form collected and

compiled at local, county, provincial, and national levels into the form required by KASM. Such a data system would not only facilitate flexible disaggregations but would also facilitate keeping data in the model up to date as new statistics and other information became available.

6. As we have seen in earlier chapters, it is often difficult or impossible to estimate model parameters from recorded data series. In some cases, parameters are "estimated" by manually tuning the model to track recorded time series. This process can be greatly improved by applying optimization packages to KASM which have been developed [2] to find values for key parameters which optimize the model's fit to recorded time series.

7. Finally, the ease with which KASM can be used by decision-makers, and hence its credibility, can be increased with the use of a conversational, interactive language to interface the user with the model. Such a language has been developed [7, 8, 9] which enables the user to interact with the model to change data, make decision assumptions, and make decision runs.

FOOTNOTE

[1] Other studies had already investigated investment options in crop improvement research and extension. For example, see [3]. Indeed, this study, which used KASM as one of its analytical tools, provided the analytical basis for decisions by the Korean and U.S. governments to finance and carry cut a crop improvement research program in Korea, now underway.

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CHAPTER 15

USE OF THE KASS MODEL IN ANALYSIS OF KOREA'S LAND AND WATER DEVELOPMENT POLICY ALTERNATIVES

Richard D. Duvick

Introduction

Korea is a land-short country that continues to face the problem of providing adequate food for its population. In 1974, a population of 34.7 million people was dependent on a cropland base of only 2.238 million hectares, or approximately .064 hectares per person. Population growth averaged about 1.8 per cent per year between 1970 and 1975 and is expected to grow at an annual rate of 1.6 per cent per year from 1975 to 1985. Loss of cropland has been 12,000 to 15,000 hectares per year. All of these factors put added pressure on the need to increase agricultural production.

Rice and other grains have traditionally been the major foodstuff in the Korean diet. A major policy goal of the Korean government has thus been to become self-sufficient in rice and to improve the self-sufficiency of all other food grains: mainly barley, wheat, pulses, and potatoes. Various means are available to increase production at a faster rate than consumption and, hence, to improve these self-sufficiency percentages. Better seed varieties and improved cultural practices can increase production. Likewise, lower milling rates, riceless days, and other administrative measures which cause changes in the diet can reduce consumption. But another area which has received, and will continue to receive, great attention in Korea is land and water development. This involves improving the land base through irrigation, drainage, and consolidation projects and increasing the land base through reclamation.

Increases in agricultural production are complemented by improvements in the present land base and associated water management systems. At the same time, there is potential cropland that can be developed to add to the cropland base. A great deal of concern has been expressed in Korea over the potential for increasing agricultural production through development of Korea's land and water resource.

The major purpose of the research reported in this chapter is to evaluate various alternatives in the future development of Korea's land and water resources in relation to the future food needs of the country. Since many development practices require a number of years before their full potential is reached, the analysis examines the 25-year period to the year 2001.

Procedure

The first requirement was to gather data on various aspects of land and water development (L&WD). Since detailed data by region were out of the question, it was decided to evaluate development on a national basis only. Two basic categories of L&WD activities were defined:

(1) Improvement of the present land base. Irrigation, drainage, and land consolidation improve the quality of cropland and increase its productivity (See Table 1 for a summary of the basic effects.)

(2) Additions to the present land base. Reclamation of tidal land for paddy land and conversion of idle and forested slopeland to cultivated upland increase the quantity of cropland

Following this basic framework, the area of potential land for each type of development activity was determined. At the same time each type of development activity, such as irrigation, was subdivided into three cost classes--low, medium, and high cost of development. Specific estimates were also made of the effect of each type of development on crop yields and cropping intensity, in line with the framework suggested in Table 1.

This provided the primary data necessary to develop a polyperiod linear programming model. The LP model selected land and water development activities by type and cost class that would maximize the total production of food grains over the 1977-2001 period, subject to investment and other constraints defined for various alternatives. Output of the model included the amount of each activity to develop by time period (e.g., hectares of low-cost irrigation to develop in 1977-1981), total hectares of paddy and upland, yields of rice and the other food grains, and double-crop ratios resulting from the combination of activities developed. Thus the LP model not only selected the mix of activities and period for development, but provided measures of the combined effects of these activities on future yields, acreage of cropland, and land-use intensity.

These data were then used to modify the basic input data on yields, changes in paddy and upland, and double-crop ratios within the KASS model. Output of the KASS model was then used to compare and analyze

Table 1. Theoretical Basis of Benefit for Land and Water Improvement Activity

Crop	Irrigation	Surface Drainage	Sub-Surface Drainage	Land Consolidation
Rice	1. Increases average yield by improved water 2. Allows higher average yield to be achieved through use of Tongil varieties 3. Additional paddy land is created	1. Increases average yield by prevention of flood damage	1. Increases average yield by a. Improving soils structure b. Removal of harmful salts c. Better aeration of root zone d. Allows more Tongil variety rice to be grown	1. Increases average yield by a. Improved water management b. Improved drainage c. Better roads promote increased use of inputs such as fertilizer, lime, and insecticides d. Allows more Tongil variety rice to be grown 2. Average yield is decreased due to loss of land for roads, canals, etc.
Second Crop	Allows additional double-cropping because of improved water control and drainage	No effect	Allows double-cropping, since adequate drainage of subsoil water improves the chances of getting into the field on time	Allows additional double-cropping because of improved drainage and reduction of labor requirements in peak seasons

the alternative land and water development strategies with respect to their effect on such factors as cropping patterns, livestock inventory, self-sufficiency levels, and the quantity and value of imports and exports.

In summary, once the basic data were developed, the sequence of actions for each policy alternative involved three major steps:

(1) Definition of alternative constraints--investment per period, emphasis on specific development activities, etc.

(2) Determination of development patterns--cropland, yields, and cropping intensity--through use of a polyperiod linear programming model

(3) An expanded analysis of each alternative with the KASS model. Key output data were agriculture and fishery production, self-sufficiency ratios, per capita food consumption, feed grain demands, and the value of the total food and feed grain deficit

Finally, the results of the various alternatives were compared and analyzed. The base alternative examined was a "no investment" alternative; i.e., what would happen if no further land and water development were done in Korea. Results from the other alternatives were then compared with the base run to evaluate benefits from the various levels of investment and development patterns.

This combination of analytical tools, an LP model and a sector simulation model, also led to the involvement of numerous organizations and individuals in conducting the analysis. The study originated with economists at the Agricultural Development Corporation, the semiautonomous land and water development agency of the Korean Ministry of Agriculture and Fisheries. Cooperation with the Korean Agricultural Planning Project's (KAPP) Program and Project Evaluation Analyst helped in definition of the project and development of the polyperiod LP model. Staff members from KASS and NAERI modified and ran the KASS model. These joint efforts were not only beneficial to the L&WD analysis, but also contributed to improvements in the KASS model.

Examples of the Analysis and Results

The polyperiod LP model was used to determine the combination of development activities--irrigation, drainage, tidal land reclamation, etc.--that would maximize production of food grains over the 1977-2001 period. The model was constructed to allow investment to occur during five-year periods coinciding with the periods covered by the five-year economic development plans. Activities are chosen by type and year to maximize production, subject to the capital and other constraints of the model. All costs are in terms of 1975 prices. Investment activities were restricted to the 1977-1996 period. This allowed full production potential to be achieved by the year 2001, despite the time lag from start of construction to full realization of agricultural production potential.

A series of runs was made with varying levels of capital investment. The capital investment level was related to an annual rate of expenditure ranging from 30 billion to 145 billion won. In 1975, the level of investment in land and water development projects was about 60 billion won. The highest level of spending, 145 billion won per year, provides enough investment to develop all potential areas during the 20-year period. Additional runs were made where activities during the 1977-1981 period corresponded to plans being considered by the Ministry of Agriculture and Fisheries (MAF) as a part of the drafting of the Fourth Five-Year Development Plan.

LP Model Results

To illustrate the analysis, partial results from two alternatives are presented and discussed. The first, Alternative A, is the "no investment" alternative, which assumes no further land and water development in Korea. This alternative is based on the assumed annual losses of paddy and upland, no change in double-crop ratios, and yield projections for food grains. The assumed loss of 5,000 hectares of paddy land and 8,400 hectares of upland each year results in a steadily declining land base. Rice yields are assumed to reach a maximum potential of 5.05 metric tons per hectare by the year 2001. This is based on adoption of improved varieties of rice and improved crop management. However, with this alternative, high-yielding varieties, such as Tongil and Yushin, are limited to 600,000 hectares of the present paddy land, due to inadequate irrigation and drainage on the remaining paddy.

The second, Alternative B, is labeled 60 Billion. This corresponds to 60 billion won of investment available per year during each of the years 1977-1996. The results from the LP model for this alternative are shown in Table 2. (Since under Alternative A there is no investment, no improvement in the present land base, and no creation of new land base, there are no results to include in Table 2.) The Alternative B level of investment is sufficient to develop all potential areas of irrigation, subsurface drainage, land consolidation, and slopeland reclamation. However, irrigation projects are largely deferred to later periods, while slopeland reclamation, land consolidation, and subsurface drainage are brought in during the early periods. In addition, 71 per cent of the surface drainage area and 37 per cent of the tidal reclamation can

Table 2. Investment and Development Activities from LP Model for Alternative B--60 Billion Won Per Year Investment, by Period, Korea, 1976-1996

Activity	Unit	Period of Development						Percentage of Potential Area
		1976[1]	1977 to 1981	1982 to 1986	1987 to 1991	1992 to 1996	Total 1976 to 1996	
Total Investment	Billion Won[2]	73	300	300	300	300	1,273	---
Ways of Improving Present Land Base								
Irrigation	1,000 Ha.	31	43	0	0	168	242	100
Surface Drainage	1,000 Ha.	0	7	0	51	68	127	71
Subsurface Drainage	1,000 Ha.	23	30	33	37	0	122	100
Land Consolidation	1,000 Ha.	50	184	80	0	0	314	100
Ways of Creating Added Land Base								
Reclaiming Tideland	1,000 Ha.	0	8	82	48	13	152	37
Reclaiming Slopeland	1,000 Ha.	20	115	0	0	0	135	100

[1] These represent planned acreages to be developed during 1976.

[2] 1975 prices.

[3] Acreage of tideland reclaimed is shown during the period it comes into production. However, the majority of investment requirement was generally made during the preceding period.

be completed by 1996. This level of tidal reclamation creates 152,000 hectares of new paddy.

The combined effect of the amount of land and water development activities selected and their period of development under Alternatives A and B provide estimates of cropland, double-crop ratios, and food grain yields, required as input data for further analysis by the KASS model (Table 3). Hectares of cropland, the double-crop ratio on paddy, and rice yields are all higher for the 60 billion won alternative than for the "no investment" alternative. However, yields of all other food grain crops are depressed, due to the conversion of slopeland to upland, since the yields are assumed to be only 80 per cent of yields on present upland. The increase in rice yields is due to the land improvement activities. In fact, rice yields for the 60 billion won alternative would be even higher, except that yields on reclaimed tidal land are assumed equal to the "no investment" level.

KASS Model Assumptions

Several major assumptions were made in utilizing the KASS model. Naturally, other assumptions could be made. However, it was felt that these were reasonable assumptions which would help to abstract from peripheral issues and simplify analysis.

(1) The basic data and relationships of the KASS model, such as import and export price projections, direct and cross price elasticities, income elasticities, population projections, livestock data, and crop yield estimates were accepted. However, yield estimates for the six food grains were based on the LP solutions for each alternative, as described above

(2) The acreage of fruit, vegetables, mulberries, tobacco, and industrial crops would never exceed the acreage planted to that crop in 1974. Therefore, changes in crops grown were largely reflected in the six food grains

Table 3. Output of LP Model Used as Input for the KASS Model, No Investment and 60 Billion Won Alternatives, Korea, 1981, 1986, 1991, 1996, and 2001

Item	Unit	Alternatives by Year									
		No Investment					60 Billion Won				
		1981	1986	1991	1996	2001	1981	1986	1991	1996	2001
Cropland											
Paddy	1,000 Ha.	1,169	1,144	1,119	1,094	1,069	1,138	1,202	1,242	1,281	1,263
Upland[1]	1,000 Ha.	505	463	421	379	337	631	589	547	479	437
Double-Crop Ratio											
Paddy	Percent	50	50	50	50	50	62	66	69	70	70
Upland	Percent	72	72	72	72	72	72	72	72	72	72
Food Grain Yield[2]											
Rice	MT/Ha.	4.00	4.26	4.53	4.79	5.05	4.14	4.37	4.71	5.21	5.51
Barley	MT/Ha.	2.55	2.67	2.79	2.90	3.02	2.41	2.88	2.67	2.77	2.88
Wheat	MT/Ha.	2.57	2.71	2.85	2.99	3.13	2.46	2.62	2.73	2.86	2.99
Other Grains	MT/Ha.	1.51	1.75	1.99	2.23	2.47	1.41	1.66	1.88	2.09	2.30
Pulses	MT/Ha.	1.28	1.39	1.50	1.61	1.72	1.21	1.32	1.42	1.51	1.60
Potatoes	MT/Ha.	4.74	5.11	5.48	5.85	6.23	4.46	4.88	5.21	5.53	5.86

[1] Upland for summer grains only. Additional upland is available that is devoted to vegetables, fruit, tobacco, mulberries, and industrial crops.

[2] Polished grain equivalent.

(3) The ROK government would continue the policy of maintaining a constant real price for rice throughout the 1976-2001 period

(4) The government would maintain a constant real price for barley and wheat only until 1980. After 1980 wheat and barley prices would be determined by market forces

KASS Model Results

KASS Estimates of Cropping Patterns and Livestock Inventory

Cropping patterns from the KASS model for the two alternatives are shown for 1981, 1991, and 2001 (Table 4). The "no investment" alternative results in large decreases in barley, pulses, and rice, while wheat and potato hectarage increase. Total hectares of crops grown decline from 3.1 million hectares in 1981 to 2.7 million in 2001. For the 60 billion won alternative, rice hectares increased, smaller reductions occurred for barley and pulses, and larger increases occurred for wheat and potatoes. Overall hectares of crops grown increased during the intervening years but declined in 2001.

Expansion of pork, eggs, and broiler production was fixed within the KASS model, so their output remained the same for all alternatives. But beef and dairy cow numbers were reduced under the "no investment" alternative. Inventory levels and production of livestock and poultry were assumed equal for all alternatives in 2001 to simplify the comparisons on feed grain imports, self-sufficiency percentages, and other data. Crop production, however, was dependent on the acreage of cropland available in 2001.

Table 4. KASS Estimates of Cropping Pattern and Inventory of Livestock and Poultry, No Investment and 60 Billion Won Alternatives, Korea, 1981, 1991, and 2001

Item	Unit	Alternatives by Year					
		No Investment			60 Billion Won		
		1981	1991	2001	1981	1991	2001
Crops							
Rice	1,000 Ha.	1,169	1,119	1,069	1,188	1,242	1,263
Barley		816	652	462	988	831	672
Wheat		49	128	230	111	309	412
Other Grains		71	51	39	89	65	50
Pulses		284	206	152	354	261	195
Potatoes		176	202	205	206	246	231
Fruit		63	64	60	63	64	60
Vegetables		274	274	274	274	274	274
Tobacco		54	54	54	54	54	54
Mulberry		61	61	61	61	56	56
Industrial Crops		107	94	84	107	107	107
Total Crops		3,124	2,905	2,690	3,495	3,509	3,364
Livestock							
Dairy Cows	1,000 Head	146	271	385	146	301	385
Beef Cows		665	428	336	722	479	336
Sows		228	338	480	228	338	480
Poultry							
Hens	Million	22	33	47	22	33	47
Broilers		77	114	162	77	114	162

Self-Sufficiency Levels

The KASS projections show that rice self-sufficiency declines to 92 per cent in 1991 and falls to 90 per cent by 2001 under the "no investment" alternative (Table 5). Thus Korea's situation regarding rice would require imports over the entire period. However, expected declines in per capita consumption and increases in yields would keep the rice deficit to around 10 percentage points.

Investment of 60 billion won per year would only increase rice self-sufficiency four percentage points by 1981 but would allow 15 and 26 percentage-point increases in 1991 and 2001, respectively. This is typical of the problem facing Korea. In the short run, increases in rice self-sufficiency due to land and water development are limited; but in the long run, large surpluses may be possible. The small impact in the short run results from the three- to five-year period necessary before reclaimed tidal land can be cultivated and another five to seven years before maximum rice yields can be achieved. But in the long run, the reclamation of about one-third of the potentially reclaimable tidal land, combined with an expected decline in per capita consumption after the early 1980's, suggests that Korea could move into a surplus rice situation.

Korea would not be able to be self-sufficient in *both* barley and wheat, regardless of cropping pattern or investment alternative. Yield and price effects within the KASS model bring about increased wheat acreage in both alternatives shown here, but wheat self-sufficiency is still only 41 per cent under the 60 billion won investment alternative. Barley shows a six per cent deficit in 2001 under the same alternative,

Table 5. KASS Estimates of Self-Sufficiency Percentages of Food and Feed Grains and Value of Agricultural Exports and Imports, No Investment and 60 Billion Won Alternatives, Korea, 1981, 1991, and 2001

Item	Unit	Alternatives by Year					
		No Investment			60 Billion Won		
		1981	1991	2001	1981	1991	2001
Self-Sufficiency[1]							
Rice	Percent	88	92	90	92	107	116
Barley	Percent	91	87	68	103	102	94
Wheat	Percent	6	15	24	14	31	41
Other Grains	Percent	100	100	83	100	100	100
Pulses	Percent	89	62	38	97	70	39
Potatoes	Percent	108	140	164	117	161	185
Food Grains	Percent	75	76	72	82	90	95
Food and Feed Grains	Percent	67	64	57	73	76	74
Feed Grain Imports							
Quantity	1,000 MT	1,293	1,959	2,950	1,124	1,715	2,771
Value	Billion Won[2]	86	130	196	75	114	183
Agricultural Export-Import							
Exports	Billion Won[2]	1,864	2,245	1,923	1,870	2,235	1,932
Imports[3]	Billion Won[2]	395	807	1,326	338	695	1,183
Balance of Payments	Billion Won[2]	1,469	1,438	597	1,532	1,540	799
Food and Feed Grain Balance of Payments	Billion Won[2]	-303	-377	-538	-242	-222	-269

[1] Self-sufficiency compares total production to requirements for food, seed, processing, and losses. It does not include feed requirements for livestock, except in the Food and Feed Grain Self-Sufficiency calculation.

[2] 1975 prices.

[3] Includes import of agricultural products for food, feed grain imports, plus imports of fertilizers, chemicals, and other inputs to produce agricultural products.

but barley self-sufficiency for food use is not expected to be a problem, providing farmers have adequate price incentives to grow barley.

Potatoes show up in surplus quantities in both alternatives. This surplus is assumed to be used for livestock feed. Pulses' self-sufficiency falls to under 40 per cent in both alternatives; but some acreage devoted to potatoes could be shifted to pulses, if this seemed to better serve national interests.

Self-sufficiency of all food grains is never achieved with either of these alternatives. However, very substantial improvements are made with the investment alternative over the "no investment" alternative. Thus, as an aggregate quantity measure, Korea could produce 95 per cent of all food grains needed in 2001, with annual investment in land and water development of 60 billion won. But the self-sufficiency percentages for the individual commodities emphasize that substantial imports of wheat and pulses will still be needed. This underscores the need to review the monetary trade balance, as well as to look at composite food indexes on quantities.

The Food and Feed Grains Self-Sufficiency Measure also accounts for the feed requirements for livestock and poultry. For both alternatives, Korea is expected to continue to face a major deficit of total food and feed grain demands. With the "no investment" alternative, self-sufficiency continues to decline; while with the 60 billion won alternative, the situation remains about the same throughout the period.

Agricultural Exports and Imports

The summary projection data on exports and imports of agricultural show a continuing favorable balance of payments for agricultural and fishery products. This is largely due to projected exports of fish and silk, with lesser amounts of tobacco and pork. In the 60 billion won alternative, surplus rice is also exported, but surplus potatoes are assumed to be used as feed grains. Agricultural imports include beef, feed grain, wheat, fruit, pulses, and vegetables, generally in this declining order of importance in terms of value.

Since the primary emphasis of this study was on potential food and feed grains production. a separate balance-of-payments figure was calculated on just food and feed grains (Table 5). This indicates a deficit. However, the cost of this grain deficit would be substantially reduced from the "no investment" if the 60 billion won investment alternative were successfully carried out. In 1981 the grain deficit could be reduced by 66 billion won, and the reduction would increase over time. The major saving occurs from the added food grain production. The data on feed grain imports show only a nine-billion-won saving in 1981, compared to the total food and food grain saving of 66 billion won in that year.

When comparisons are made of a larger number of alternatives (11 alternatives were analyzed during the course of the study), the self-sufficiency percentages calculated by the KASS model allow judgments to be made of the effectiveness of various alternatives to meet future food demands. Likewise, the balance of payments indicates the trade balance advantages or disadvantages of the various alternatives to Korea's economic well-being.

Using data on annual savings in food and feed grain balance of payments and annual investment costs, an internal rate of return is calculated for each alternative. These provide an additional measure of the economic worth of each land and water development alternative. Of course, in making final investment decisions, the Korean government considers a variety of factors in addition to the considerations presented here.

Summary

Use of the KASS model to analyze alternative development patterns of Korea's land and water resources has provided a guide to potential supply and demand for food in Korea. The analysis is, of course, highly dependent on several key projections on yields, population, and per capita consumption. Therefore, sensitivity testing of key variables was accomplished and documented in the study report for the Korean government [1].

The approach used in the study incorporated a polyperiod LP model and the KASS model to define and evaluate various development strategies. A strong feature of both models is that they maintain internal consistency of the numerous relationships. Future work on land and water development in Korea will be able to use KASM with the more sophisticated technology change component (CHANGE) developed by Dr. Jeung-Han Lee (see Chapter 10). The model incorporates the relationships presently included in the polyperiod LP model, plus numerous other relationships. In addition, it can be utilized in conjunction with the KASS model or run independently, as was done with the LP model.

The full analytical report has been utilized by several organizations. ADC and MAF have used it for supporting material relating to preparation of budget requests for land and water development in Korea's Fourth Five-Year Economic Development Plan. It also provided a strong background for critical examination of the land and water development activities proposed by MAF for the Fourth Five-Year Economic Development Plan. In addition, the quantification of potential food grain supply and demand for Korea under various assumptions of investment in land and water development, future diets, and future yields is of interest, not only to MAF and other Korean ministries, but to international lenders, such as the World Bank (International Bank for Reconstruction and Development) [2].

Development strategies could be defined in a different manner in order to allow a more direct comparison of the specific development methods--irrigation versus drainage versus tidal reclamation, etc. But the present analysis has been useful in examining future investments in land and water development and has provided basic information that has contributed to the development of Korea's Fourth Five-Year Economic Development Plan, as well as guidelines for longer-term investment requirements.

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PART THREE

SUBSECTOR MODEL EXAMPLES FROM KOREA

CHAPTER 16

THE GRAIN MANAGEMENT PROGRAM MODEL

Forrest J. Gibson

Introduction

The Korean Grain Management Program (GMP) model is a major supplementary component of the Korean Agricultural Sector Simulation (KASS) model being described here. The major food grains--namely, rice, barley, and wheat--are identified explicitly in the KASS model along with 15 other agricultural commodities. The strength of the KASS model is fairly uniform over all commodities identified, and problems relevant to food grain can be analyzed in as much depth as other commodities. However, the broad design of the KASS model, encompassing the entire agricultural sector with its linkages to the nonagricultural sector and long-term planning horizons of 15 to 25 years, must by necessity limit the depth of investigations into problems relevant to particular agricultural commodities such as food grains. Because food grains are by far the most important agricultural commodity group in Korea, more depth and detail is often needed in studying problems related to these commodities than can be provided from the KASS model alone. The GMP model focuses solely on the Korean food grain system and grain management program. With this sharp focus on the food grain portion of the agricultural sector, the GMP model can be used to supplement the broader KASS model and provide insight and analytical capacity into food grain problems not otherwise possible.

In this chapter the GMP model will be described in general terms. The objective is to convey a general understanding of the overall concept of the model. This includes (1) the felt need and objectives of the model; (2) general concepts, rationale, and techniques underlying its design; and (3) what the model can do to assist researchers and decision makers in Korea. Some equations are found in the discussion to aid in the description of key concepts and relationships. However, emphasis is on the "whys" or rationale behind the design aspects of the model rather than on the specific "hows" or mathematical relationships of the model. Technical specialists interested in a thorough description of the mathematical equations and relationships of the model must look elsewhere [3] for this type of description, for such descriptions do not mix well with the intent of this chapter.

Need for the GMP Model in Korea

Since the original Grain Management Law was enacted in 1950, the basic objectives of all grain management programs in Korea have been to assure adequate food grain supplies for the Korean people and to stabilize the national economy which is greatly affected by the domestic food grain system. There is no question about the importance of food grain programs to the Korean people and national economy. The three major food grains--rice, barley, and wheat--account for 70 percent of the total average daily calorie and protein intake of the Korean people [14]. Rice production alone provides 50 percent of the average cash income of Korean farmers, while urban consumers spend over 32 percent of their total household budget (64 percent of their food and beverage budget) on rice, barley, and wheat consumption. Cereal grains (of which rice, barley, and wheat comprise 95 percent) have a weight of 0.18 in the consumer price index. This far exceeds the weight given any other commodity group, including energy, housing, and clothing. Because of this large impact on the national economy, the Korean government must play a very active role in grain markets to assure stabilized food grain prices. In recent years this has been a very costly undertaking as indicated by the deficit in the Grain Management Special Account [5] which has risen from $5 million in 1972 to well over $700 million by the end of 1975.

Korea is also a chronic food grain deficit country and must depend on foreign sources every year to supplement her inadequate domestic supplies. Self-sufficiency goals for rice and barley have been hard sought by government officials for many years. New high-yielding rice varieties [14] have boosted rice production nearly 18 percent over the past five years, but requirements for food grains continue to grow faster than domestic production.

The complexity of managing food grains in Korea is evidenced throughout history, back through the days of Japanese occupation [8]. Chronic problems of assuring adequate supplies, price stabilization, and managing existing grain stocks occur today in much the same manner they have occurred over the past thirty years. Means of reckoning with food grain problems have also remained very similar to old methods. Mainly, these consist of human judgements by decision makers who, drawing on their own knowledge and the knowledge of others, attempt to construct a mental picture of the complex interrelationships within the food grain system and visualize the consequences of alternative courses of action. Quantitative analyses of critical grain management problems are sometimes available to the decision maker, but these are generally done on an *ad hoc* basis and often are either too simplistic, require too many unrealistic assumptions, or are too theoretical to have any value in attacking real world problems.

Objectives of the Model

The design of the GMP model has two main objectives: (1) to approximate, at an acceptable level of detail and accuracy, the real world (dynamic) food grain system in Korea as it responds to various grain management programs, policies, and decisions; and (2) to design control systems for the model which will enable its use as an on-line grain management tool to be used by government administrators in directing existing grain management programs to achieve prescribed objectives.

The aim of the first objective is to furnish the policy analyst and decision maker an analytical tool by which they can speedily investigate the potential consequences (goods and bads) of alternative proposed solutions to a variety of chronic grain management problems existing in Korea today. The detail required from the model is dictated by the kinds and amount of information analysts and decision makers must have about the performance of the food grain system to make sound selections among alternative programs and policies under investigation. The accuracy required from the model need not always be in the precise magnitude of the variables generated but, rather, in the capability of producing valid comparisons among alternatives being studied.

The second objective is aimed at developing a set of management strategies which can be adopted by government officials in administering existing grain management policies. Seasonal food grain price control is the main concern of this objective, since it remains one of the most perplexing and costly problems facing grain management officials today. Ideally, if the GMP simulation model can be made to approximate the real world dynamic Korean grain system, with supply, demand, and price relationships responding in a realistic manner, then the decision rules developed for controlling market prices generated by the model should infer relevant real world decision rules required to steer actual market prices toward seasonal price policy objectives.

General Description of the Model

Thus far we have viewed the GMP model from a very high altitude and done little more than describe its relationship with the overall agricultural sector model, indicate the motivation for focusing sharply the food grain subsector in Korea, and state the general objectives for the model. We will now drop altitude slightly and describe the model in more specific terms.

Method

The general systems simulation approach (GSSA) was utilized in the design of the GMP model (see Chapter 1 and also [6,12]). Techniques from various disciplines (including systems design, econometric analysis, economics, operations research, linear and nonlinear systems, and automatic feedback control theory) were used in the model development. The model itself is a nonlinear, dynamic system model with some time-varying parameters.

The model is fully computerized utilizing FORTRAN computer language. Solutions to model differential equations are gained through numerical integration techniques stepwise through time. Each solution interval of the system model also enables the calculation of all other variables through simple algebraic relationships. Many of the model calculations are internal to the computer and are not output. Solution intervals necessitated by conditions for system stability are not always of interest in generating time series data. For example, solution intervals of 1-2 days are necessary within the computer, but users may require time series data output at only weekly or monthly intervals. Some variables are used only as intermediate variables for calculation purposes and are not meaningful in the real world. The model produces summary data at prespecified intervals which can be output in table format for the convenience of the model user.

Size of the Model

The generalized nature the GMP model, making it applicable to a broad range of grain management problems and capable of generating the kinds of information decision makers need to solve these problems, necessitates it being large in size. The model contains approximately 4,300 executable statements and generates more than 2,000 variables. Core requirements exceed 120K octal words. Execution time for a full run of the model on a CDC Cyber 70, using a simulation time increment of 1/200 of a year (1.8 days) for a two-year tun, is about three minutes CPU time.[2]

Program and Policy Issues

In its current state of development, the model has direct application to the following grain management program and policy issues:

1. The timing and quantity of government grain purchases and/or releases in order to control farm and/or urban market prices.
2. Price and, hence, government subsidy requirements of government-regulated wheat flour.
3. Location, quantity, and movement of government-controlled grain stocks.
4. Quantity and scheduling of foreign grain imports.
5. Purchase and release prices of government grains.
6. Seasonal price pattern policy objectives.
7. Government purchase programs for domestic grains.
8. Food grain self-sufficiency.
9. Programmed grain consumption of farm and nonfarm consumers.
10. Foreign grain loan repayment schedules.
11. Grain milling extraction rates.
12. Warehouse construction programs.

More will be said about some of these important policy issues later in the chapter when we describe the Policy Orientation of the Model.

Model Design

The design of the GMP model can be organized into three different categories: (1) grain system operations, (2) policy orientation, and (3) system performance. Model design under the *first* category is used to approximate the dynamic behavior of the real world food grain system in Korea. This portion of the model simulates the production, importation, movements, processing, storage, and disappearance of food grains in Korea over time. Economic forces--namely, food grain supply, demand, and prices--which govern much of the system operations behavior are also simulated in this portion of the model. The system operations model is designed and parameterized to reflect real world system structure, human behavior, management decisions, and system constraints. The *second* category of model design, policy orientation, has the purpose of orienting the model toward usefulness as an analytical device for studying particular grain management problems. The *third* category of design, system performance, is necessary to provide model users with specific information about the (simulated) performance of the real world system so that well-informed choices can be made among alternative management strategies under study. Self-checks into actual model performance for tuning, testing, and validation purposes, such as how well it tracks past data, are also built into this portion of the model. More will be said later regarding model design under each of these categories.

Disaggregation

To provide the level of detail required by potential users and to represent the state of the food grain system extensively enough to capture the important interrelationships and dynamics required to fulfill model objectives, the GMP model is disaggregated across six dimensions. These dimensions are summarized in Table 1.

Table 1. GMP Model Disaggregation

Subsectors	Population	Food Grain Commodities
Farm	Farm	Rice
Urban households	Nonfarm	Barley
Private Market		Wheat
Government		

Grain Forms	Position Points	Government Warehouse
Rough	Production areas	Low-temperature
Hulled	Seaports	Class A
Polished (pressed)	Consumption area terminals	Class B
Flour and flour products	Retail sales stores	Class C
		Auxiliary

Subsectors

The GMP model disaggregates the Korean grain system into four subsectors: (1) farm, (2) urban and nonfarm consumer households, (3) private market, and (4) government. Generally, grain management program objectives are aimed at individuals comprising these components of the overall grain system and may be different for one subsector than for another. Behavior characteristics are also different in each subsector. Farm consumption behavior differs from urban in that farmers must decide whether to consume or market their food grains for needed cash. The private market differs from government marketing channels in that it consists of entrepreneurs motivated by profit incentives to move and store grain, whereas the government is motivated to carry out grain operations in order to achieve grain policy objectives for the entire system.

Food Grain Commodities

Food grain commodities identified by the GMP model are rice, barley, and wheat. These are the major food grains in Korea, accounting for over 95 percent of total human food grain consumption. Rice is by far the most important food grain commodity, accounting for about 51 percent of total human food grain consumption. Barley and wheat follow rice in importance, with each of these grains accounting for around 22 percent of total food grain consumption.

Grain Forms

The GMP model traces through time all physical operations on food grains from planting to final consumption. All food grains undergo physical characteristic changes through processing before they are consumed by humans. The rice hull remains on the grain after harvest. This hull provides a protective shell around each kernel and enhances the storability of the grain. Common practice is to leave the rice in unhulled (or paddy) form until shortly before it is marketed or consumed. Paddy rice, however, is more bulky than hulled rice and requires twice the storage space. Rice processing can be divided into two stages, hulling and polishing. The hulling process merely knocks the outer hull off the grain, leaving what is commonly called hulled (or brown) rice. Brown rice does not have the storage qualities of hulled rice but still maintains its taste qualities during prolonged storage much better than in the final polished form. Rice is imported in brown rice form and polished in government-licensed mills shortly before release onto the market. Rice hulls have little economic value but are used as fill for pillows and mattresses and also serve as a good absorbent. Rice bran, however, has a high economic value and is used as a high-quality animal feed and in the production of rice bran oil.

Both common and naked barley are produced in Korea. Each of these grains have different physical characteristics after harvest, but after milling the polished form of the two grains appears similar. Common barley has a fibrous hull firmly attached to the grain. This hull must be ground off with the bran by-product going mainly to animal feed. Naked barley appears somewhat similar to wheat after harvest with a skinlike covering over each kernel. This covering is ground off during the milling process with the bran by-product also going mostly to animal feed products. Barley can also undergo further processing into pressed form. At this stage of processing, polished barley is parboiled briefly, dried, and rolled to enhance the cooking qualities of the grain, especially when mixed with rice. Supplemental nutrients are added often to pressed barley.

Since 1971 the Korean government has undertaken a program of mixing rice and pressed barley together. Currently they are providing a 70/30 mix ratio of rice to pressed barley. The program has intensified in recent years and now all government rice is mixed with barley before release.

The vast majority of wheat consumption in Korea is in the form of wheat flour and wheat flour products. Over 90 percent of the wheat consumed in Korea comes from wheat imports which are milled into flour by members of the Korean Flour Millers Industrial Association (KOFMIA) and sold to various wheat flour processing industries throughout the country.

As indicated in the preceding discussion, food grains can take on a multitude of forms prior to human consumption. The GMP model disaggregates by grain forms but only to the extent of absolute necessity, since disaggregation in any dimension means added complexity to the model. Table 2 indicates model disaggregation (and aggregation) of food grains by form.

Table 2. Model Disaggregation of Food Grain by Form and Commodity

Commodity	Unhulled (Whole Grain)	Hulled	Polished (Pressed)	Flour (Flour Products)
Rice	X	X	X	
Barley	X		X	
Wheat	X			X

Position Points

The GMP model keeps tabs on the physical location of food grains until final disappearance. Position is an important dimension of system disaggregation when it comes to parameterizing storage and flow capacities of the model to reflect realistic values. Domestic grains must move from farm positions through commercial marketing channels, undergoing processing and storage over time, before they eventually arrive into urban consumer households for consumption. Imported grains must move into seaport facilities from foreign countries, move into urban areas, undergo processing, and move into retail sales outlets before they arrive into urban households. In general, domestic grains are processed and stored in production areas and move into consumption areas as required to meet urban demand requirements. Imported grains are processed in urban areas.

Government Warehousing Classes

The last dimension of GMP model disaggregation is classification of government-controlled warehousing facilities for food grains. Although of lesser importance than other disaggregations of the model for immediate use, this dimension enables the use of the GMP in addressing grain management problems related to storage practices on government-controlled grains [4]. The model identifies five classifications of warehouse facilities: (1) Low-temperature, (2) Class A, (3) Class B, (4) Class C, and (5) Auxiliary storage. Each of these classifications of warehouses has different unit construction costs, storage charges, and storage loss characteristics over the four seasons of the year. Table 3 indicates the distribution of the five classes of government-controlled warehousing facilities as of June 1974. The distribution of these classes of warehouses changes over time with depreciation, new warehouse construction programs, etc. The GMP model keeps tabs on this distribution and simulates expected loss rates from storage over time.

Table 3. Capacity and Capacity Distribution of Storage by Class

Warehouse Class	Capacity (1,000 MT)	Percent
Low-temperature	172	11
Class A	89	6
Class B	473	32
Class C	554	37
Under Grade (auxiliary)	217	14
TOTAL	1,505	100

Source: Yearbook of Agriculture and Forestry Statistics, Grain Statistics 1974, MAF, 1974.

Grain System Operations Model

A major portion of the GMP model design is devoted to describing the time, space, and form processes of grain operations occurring within the Korean grain system. This includes the simulation of physical grain operations, such as production, importation, market supply and demand, actual grain transactions, grain movements and processing, storage, and consumption. It also includes the modeling of economic forces, such as farm and urban market prices, which have major effects on the behavior of the grain operations system. Physical processes are parameterized and constrained to real world characteristics to reflect realistic system performance.

The basic structure of the grain system operations model is found in four subsector models representing (1) farm, (2) urban or nonfarm, (3) private market, and (4) government subsectors of the real world grain system. These models are linked and become closely interrelated components of the overall system through a market price generation and transaction mechanism. Once the subsectors are linked, the grain system operations model must not be considered as four separate subsector models, but as a fully integrated system with virtually all (internal) variables being related, directly or indirectly.

In describing the grain system operations model, it is desirable to emphasize the "whole" system concept; however, it is difficult to do so when describing the model subsector by subsector. The procedure used is to describe briefly the individual subsector component models in general terms to give the reader a comprehension of thier individual attributes and functions. From there, further discussion of the model will be centered around actual system operations, such as production, importation, grain movements, storage, and consumption.

Subsector Component Descriptions

Farm Subsector

The farm subsector model is structured and parameterized to simulate the production, storage, marketing, and consumption (human and nonhuman) of food grains at the farm level. Farmers respond to past experience, cost factors, prevailing market conditions, and future expectations in their decision processes regarding farm grain management operations. The GMP model attempts to capture some of the important factors and rules going into farm decision processes and reflects the impact of these decisions as they are passed on to other subsectors and are propagated throughout the entire food grain system.

Urban Subsector

The urban demand component model simulates the demand, consumption, and food grain storage characteristics of urban consumer households. Effective market demand for food grains is keyed to both current consumption levels and household grain inventory adjustments These storage adjustments are responsive to food grain price levels, as well as to future expectation of market prices. Consumption is responsive to food grain prices and also to the level of existing household grain inventories. When inventories become critically low, reflecting inadequate market supplies, consumption is suppressed, reflecting a tightening-of-the-belt phenomenon during times of food grain shortages.

Private Market Subsector

The private market (PM) subsector model reflects the structure, constraints, and decision processes which govern the flow, processing, and storage of food grains through nongovernment marketing channels. Decision and management processes of individual participants (including collectors, assemblers, millers, shippers, commissioners, wholesalers, and retailers) of the private market are modeled. Domestic grains are purchased, stored, and sold according to rational private market demand and supply functions. Grains move into private marketing channels at various position points and are processed where appropriate. They then continue through the private marketing system to retail sales positions, where they move out of the private market subsector and into urban household storage via sales transactions. Imported wheat operations, which are handled by the private market, are also simulated.

Government Subsector

Internal government food grain operations, including domestic purchases, imports, storage, milling, transportation, and releases, are simulated in this subsector model. Decision processes required to administer existing grain management programs and policies, such as farm and/or urban price stabilization and control of reserve food grain stock level management through importation of foreign grains, are also designed into the model. This aspect of the model, however, does not strive to replicate existing real world government decision processes as the PM subsector model does for the private market. Instead, the model is designed as a tool for prescriptive analysis of government grain operations that would be necessary to achieve targeted policy objectives. The attempt of the model here is to *improve* on existing government decisions through providing insight and guidelines for government officials actively engaged in these difficult decisions.

Subsector Linkage

The four subsector components of the GMP model are linked together by a price and transaction (PAT) mechanism. This mechanism is used to interface food grain supply-and-demand relationships in farm and urban markets, generate market prices, and calculate actual grain transactions which occur throughout time.

The grain market transaction mechanism operates both in the farm and urban consumer markets. On the farm market side, government and private market demands for grains are interfaced with farm marketings. Free market decision of farmers to market into either the private or government sectors are reflected in the mechanism. These choices depend on the relative levels of government and private market demands, the relative buying prices being paid by the government and private market subsectors, and the relative convenience to the farmer in marketing into each of these subsectors. Actual grain transactions then occur so that total farm sales during any period of time are equal to total government and private market domestic grain purchases.

On the urban consumer market side, grain marketings from the private and government subsectors are interfaced with urban consumer demands for grains. Free market decisions of urban consumers to buy from either the private or government subsectors are reflected in the mechanism. These choices depend on the relative levels of government and private grain marketings, the relative selling prices of government and private market grains, and also on the relative quality of government and private market grains. Actual grain transactions then occur so that total government and private grain sales during any period of time are always equal to total urban consumer purchases.

The transaction mechanism contains parameters which can be altered to reflect government countermeasure policies designed to suppress normal free market decisions of farmers and urban consumers in choosing between private and government markets. More will be said about this while we are discussing the policy orientation design aspects of the model.

Figure 1 illustrates the basic conceptualization of the GMP component models and depicts the linkages provided by the PAT mechanism. The figure gives a simple view of the overall system concept and shows (domestic)

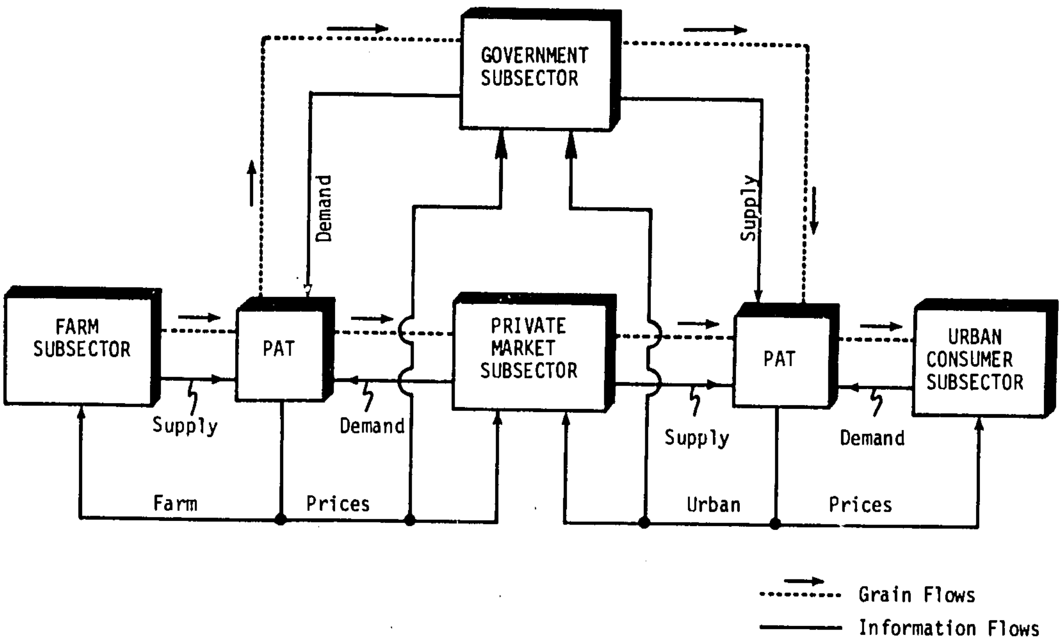

Figure 1. Grain Management Program--Model Linkage

grain flows through the marketing channels. The reader should note that all demands, supplies, and prices are indicated as being endogenous to the system. This is always true, except for government policies--such as demand and supply--which can be either endogenous or exogenous, depending on what use is being made of the model. Historical tracking experiments, which determine how well the model can reproduce historical time series data, require that government demand and supply correspond with actual purchase and release programs prevailing during the period of the model run. Government imports and purchase and release prices also must correspond to actual historical data on these series for tracking purposes. Other runs of the model may require the investigation into "what if" effects of alternative government purchase prices or alternative government purchase programs (during different times of the year) or alternative release prices. In these run modes of the model, government policies are specified by the user. In the configuration of Figure 1, the model also has the capability of calculating some government policies, such as supply and/or demand, endogenously to meet certain policy objectives, such as targeted seasonal price policies.

Many of the causal relationships of the GMP system model are not shown in Figure 1. To gain this insight, it is helpful to view the model in terms of the major system processes simulated and their interrelationships. Figure 2 is a causal map of the GMP model showing some of these interrelationships. Major grain flows are depicted in the figure. Domestic production moves into farm storage and out again (through time) to various dispositions; i.e., farm household consumption, farm livestock consumption, seed requirements, and farm commercial sales.

Farm sales are shown divided among private and government marketing channels, with some sales bypassing formal marketing channels altogether. Farm-commercialized grains then move into private and government storage and remain there until they move into urban household storage upon market transactions. Grains move out of urban household storage as they are consumed by urban people. Government imports are shown as an additional source of grain, and government uses as an additional disposition of grain. Grain storage, shown in Figure 2 by the four rectangular boxes, depicts grain ownership by farmers, urban (nonfarm) consumers, the government, and the private market. Many activities are occurring in reality, as well as in the model, within each of the grain storage blocks: grains are moving in and out of various storage facilities, being processed, stored, and moved from one position to another. Imported grains are being loaded, shipped, and discharged at port facilities, oftentimes queuing up at ports if arrivals exceed discharge capacity. All these operations require time, space, and form transformations and it is these processes that the grain operations model is simulating.

The demand and supply processes indicated in Figure 2 do not come in direct contact with grain flows but are used as information processes to calculate actual market transactions and to provide the forces that cause market prices to change over time. Both "demand" and "supply," as perceived in the GMP model, have a connotation of intent. For example, "farm supply" (or farm marketings) is the rate at which farmers make their grains available for sale--i.e., how fast they would like to sell their grains--and "government demand" represents the rate at which the government intends and is able to purchase grains from farmers,

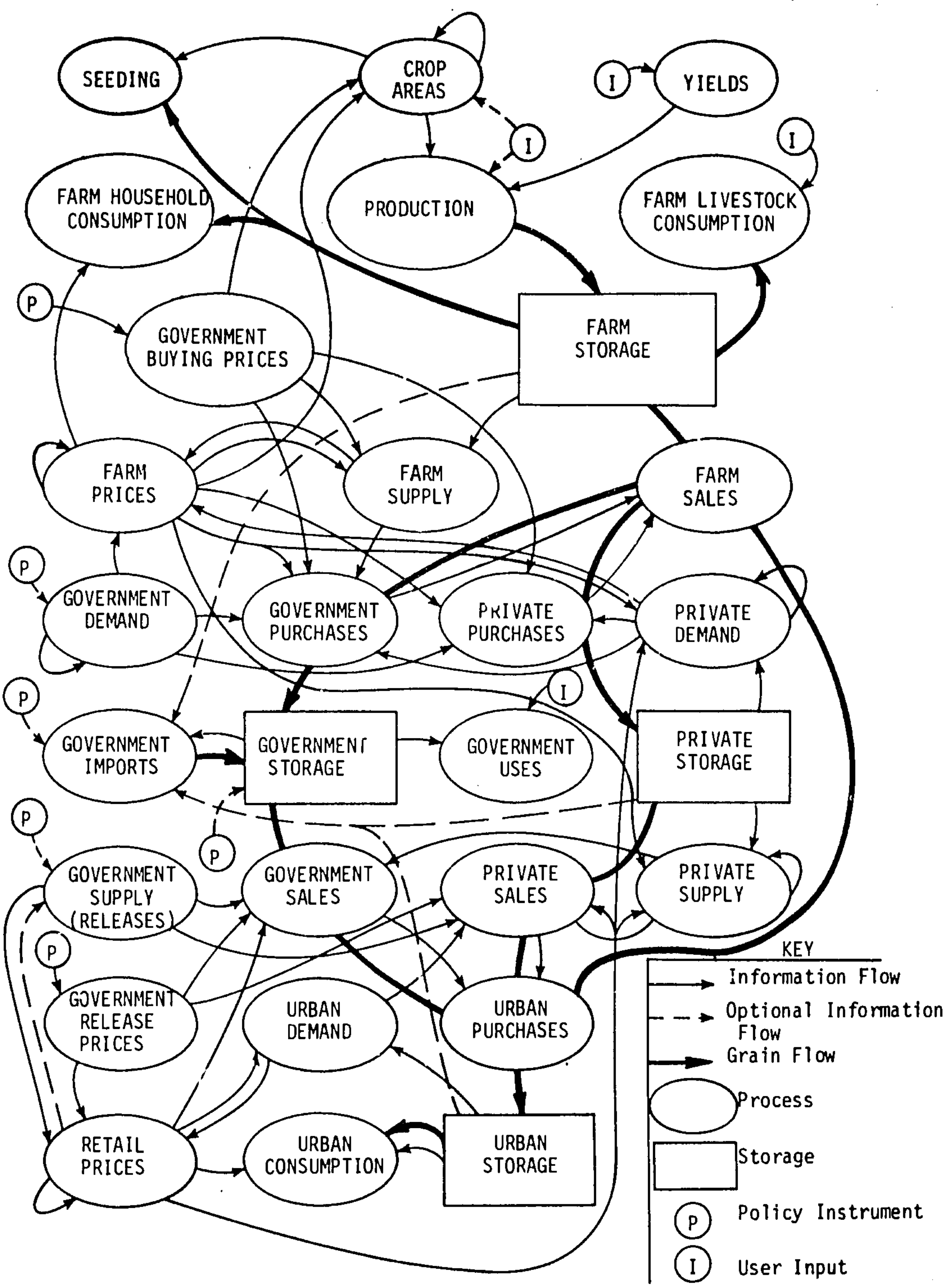

Figure 2. Causal Map of GMP Model

and so forth. "Supply," as used in the model, does not refer to the amount of grain in storage in the farm, government, or private subsectors, but means the amount each subsector is making available for sale.

To help the reader become acquainted with the causal map of Figure 2, let us consider the calculation of, say, private market purchases. Arrows entering the "private purchases" process indicate that private purchases are a function of private demand (i.e., the rate at which the private market wishes to purchase), government demand, farm supply, farm price, and government purchasing price. When the government is active in a purchase program, government demand competes with private demand for farm market supplies. Relative price differences between government purchase price and private market price affect farm choices to market into the respective markets. Also the size of the relative demands implies the accessibility of the alternative markets to farmers, affecting the farm marketings into government or private markets. Finally, farm marketings into the private market are interfaced with private demand and actual transactions (private purchases) are calculated. Other interrelationships depicted in Figure 2 can be traced in a similar way. The reader may review Figure 2 as a helpful reference in later discussion.

System Operation Processes

The GMP should be viewed in the "system" context and not as a set of isolated subcomponent models connected in a loosely-knit fashion. We will now describe in more detail some of the important processes that are simulated in the system operations model.

Domestic Production

The process of domestic production consists of both human decision (by farmers) and physical processes. Farmers decide, based on past experience and future expectations, land area to be planted to the various food grains. However, the seasonal nature of food grain production dictates closely when each crop will be planted, its maturation time, and when it will be harvested. Barley and wheat are planted in the fall and harvested in May and June of the following year. Rice is transplanted during June and harvested in the fall. Southern regions of the country are capable of producing one crop of rice plus one crop of barley (or wheat) during a single year. Some regions are very well suited for double cropping; others are not suited at all for this practice, with a continuum of suitability in between. In the critical regions during June, one can observe a sequence of barley harvest, paddy preparation, and rice transplanting operations occurring simultaneously on the same land area. New rice varieties, which allow for a shorter growing season, give more farmers the opportunity to double-crop rice with barley or wheat.

Production Decisions

Land areas planted to rice, barley, and wheat by farmers can be calculated internally by the GMP model. The user still maintains the option of specifying these land areas before a model run if he so desires, but the internal capability is there to determine the impact of various grain management programs and policies under study on domestic grain production. Several factors are seen to influence farmers' decisions and are included in this decision process. For example, relative returns between new high-yielding rice varieties and ordinary rice varieties and ordinary rice varieties influence the diffusion process of adopting new varieties by farmers. New varieties have a higher expected yield, but also require higher production costs. With more invested, farmers must assume greater risks in raising the new varieties which are also more susceptible to crop damage in bad years. Undesirable results from raising new varieties, such as large yield reductions from those expected, due to poor weather or unfavorable economic value of the new varieties can cause recidivism effects influencing farmers to change back to more reliable traditional varieties.[3] Shorter growing seasons of new rice varieties make it possible for more farmers to double-crop more barley or wheat with rice, as was mentioned before. These factors are included in the production decision calculations and used to project land areas planted to rice (Tongil and ordinary varieties) barley and wheat.

Yields are not modeled endogenously by the GMP model. Users must input expected yields, including expected yields of high-yielding rice varieties. This allows for investigating the various impacts of high or low crop yields throughout the grain system and the resulting impact on the following years' production decisions.

Production Process

The GMP is a process-oriented model in which domestic food grain production, as well as other processes occurring in the real world system, are simulated through time. Good reasons exist for needing to replicate

Human Consumption

Both farm and urban (nonfarm) food grain consumption are simulated in the GMP model. Consumption patterns vary with own- and substitute-food grain prices, as well as with income. Equation (1) indicates the Cobb-Douglas form used in the model to generate farm and urban consumption behavior for commodity i:

$$Q_i(t) = A_i P_1(t)^{\varepsilon_{i1}(t)} P_2(t)^{\varepsilon_{i2}(t)} P_3(t)^{\varepsilon_{i3}(t)} Y(t)^{\varepsilon_{iY}} POP(t) \qquad (1)$$

where Q, A, P, Y, ε, and POP are total consumption, a constant, prices, per capita income, price and income elasticities of demand, and population, respectively, for each subsector. The reader will note that the price elasticities of demand (ε_{i1}, ε_{i2}, ε_{i3}) are indicated as functions of time while the income elasticity (ε_{iY}) is not. Three sets of price elasticities are used in each of the farm and urban consumption functions to represent the seasonal nature of consumption behavior in Korea. The values of these parameters were estimated off-line for three seasons during the year. During a model run, the values of the parameters move linearly toward the succeeding set of estimated values as time evolves, so that the Cobb-Douglas functions used in the model have continuous time-varying parameters. This was necessary to achieve valid seasonal consumption behavior for farm and urban populations.

The three seasons of the year for which the consumption parameters were estimated are (1) October through January, (2) February through May, and (3) June through September. This choice of three distinct seasons is quite reasonable for the Korean situation [7]. Rice harvest occurs during October and November; thus the first seasonal period corresponds to the rice harvest and post-harvest period when farm stocks are the

the actual physical production processes in the model: the seasonal patterns of crop planting, cultivating, harvesting, and sales of food grains say much about the timing of production costs and revenue flows of farmers. Farmers' behavior patterns are strongly linked with their current financial situation and credit obligations. High interest rates, plus the normal arrangement of credit arrangements, give the farmer much incentive to recuce debt obligation soon after harvest, greatly affecting their food grain marketing patterns, which in turn affect seasonal farm market prices. Farm inventory levels also seem to have a marked effect on marketing patterns and, consequently, on farm market prices during the year. Since one of the main objectives of the GMP is to develop the capability of generating valid market price movements during the year, the need for modeling physical production processes should become evident.

Distributed delay functions, which calculate the solutions to higher order differential equations, are used in the model to simulate the various production processes (i.e., planting, cultivating, and harvesting) during the year. Land areas in the form of impulses (with no time dimension) are entered into the production process delays at precise times during the year corresponding to the beginning of each production activity. The delays then distribute these areas over the normal period of the activity, simulating the production processes. Unit cost factors are applied to each operation to give production cost flows. Expected yields (input by the user) are applied to the output of the harvest delays to generate harvest rates and the flow of domestic production into farm storage.

highest and a glut of new grain appears on the market. The second period, February through May, can be called the off-season, when no harvesting is occurring and farm stock levels of all grains are depleting. The third seasonal peirod, June through September, corresponds to the barley (and wheat) harvest and post-harvest season, when barley stocks are highest. Rice transplanting and cultivation also occurs during this period.

An additional consumption behavior characteristic included in the design of the urban subsector model is the phenomena of suppressed consumption due to low household food grain stock levels. Situations may arise where sufficient food grain supplies are not available (at any price) to urban households. In such a situation, when household stock levels are dwindling to critically low levels and cannot be replenished with additional purchases, it is reasonable to assume household consumption levels would be curtailed, even though market prices for food grain (if available) may not bring about such a reduction in consumption demand. The alternative to this assumption is that urban households would eat themselves out of food grain supplies with no concern for tomorrow. Stock levels will eventually be exhausted under either assumption, but the former seems (to model designers) to be a much more realistic view of reality. Therefore, the concept of actual food grain consumption, along with normal food grain consumption, based on household inventory stock levels is expressed in the model. The function used for suppressing normal urban consumption demand is illustrated in Figure 3. The ordinate value of the function ranges from zero to one.

The argument of the function expresses the length of time current urban household inventory level could sustain current normal urban consumption demand. The actual values of the function are, of course, unknown. Values presented in the figure represent starting "guesstimates" used in the model. Sensitivity testing can indicate the importance of accurate values of this function on model results and, thus, the need for further research in determining its true character.

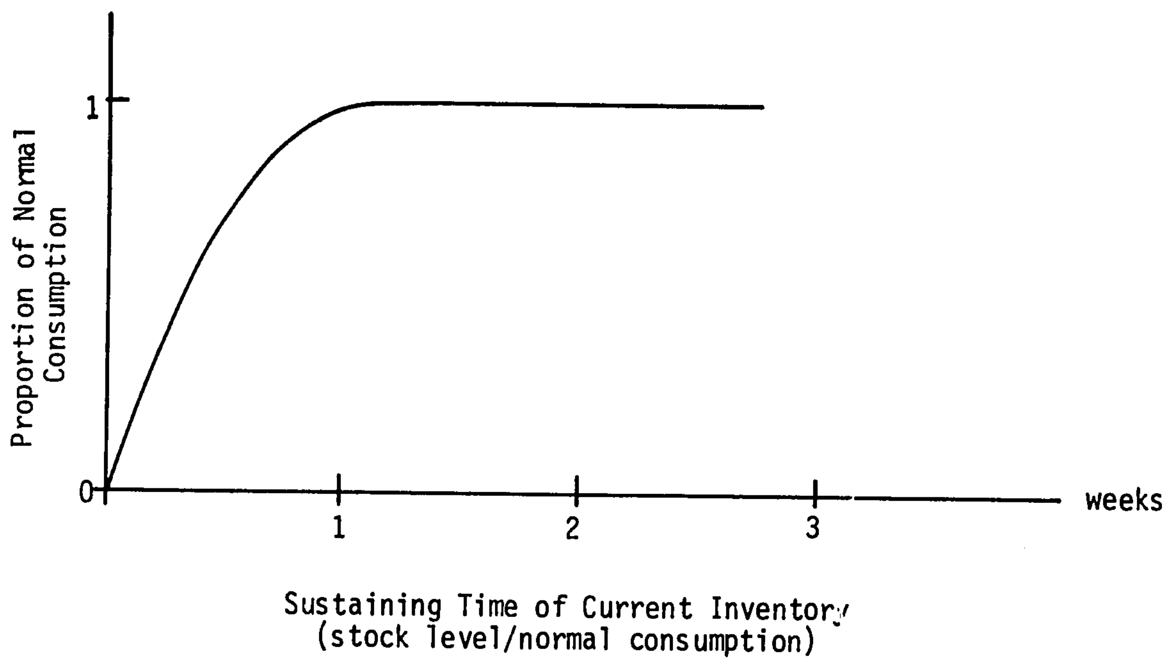

Figure 3. Urban Household Consumption Constraint Function

Grain Storage, Movements, and Processing

Grain storage, movements, and processing occur within the GMP model in much the same manner as in reality. Harvest season approaches, and domestic grains begin to flow into farm storage facilities in rough form. Farm rough grain stocks are depleted (over time) by outflows for purposes of (a) seed for planting new crops, (b) animal feed, (c) sale onto the market, and (d) milling into polished form. Most farmers utilize toll milling services of private millers, paying a toll charge of (currently) four percent of the polished product. The remaining polished grains return to farm storage from where they are either consumed on the farm or sold.

The private market subsector purchases grain from farmers in both rough and polished form. Rough grains remain in production areas until they are milled into polished form. They then move out of production-area positions by truck or train to consumption-area, terminal-point positions, from where they are distributed to retail stores for sale.

The government (under current purchasing programs) purchases domestic grains in rough form only. These grains are stored in production-area positions and milled shortly before they are moved into consumption-area positions. Government-polished grains in consumption areas are released (according to government policy) and distributed to private market retail stores registered to handle government-controlled grains.

Grain imports arrive at port facilities in unpolished form. These grains enter port storage positions and then move into consumption-area positions, where they are stored and then milled into polished grain form.

Oftentimes, imported grains are blended with domestic grains to standardize the quality of government grains before release.

Urban households also maintain grain storage. Although small in comparison to the other subsectors in the system, this storage function has a very important significance on the performance of the overall grain system. Urban household storage is depleted through consumption. As mentioned previously, urban household stock levels, when critically low, may have a dampening effect on consumption. Figure 4 depicts the major grain flows and storage functions mentioned above and represented in the GMP systems operations model.

Inventory Management

Figure 4 identifies 14 distinct food grain inventories for rice and barley represented in the grain system operations model. Not shown in the figure are the flows, processing, and storage of industrial wheat which is comprised of about 90 percent imports. Industrial wheat flour milling operations are also represented in the model. Wheat inventories are identified at three additional positions not shown in Figure 4, namely, port storage facilities (including silos), flour milling warehouses for wheat, and flour miller warehouses for wheat flour. The wheat flour product processing industry, such as noodle and bakery manufactures, is modeled only in the aggregate. Wheat grain inventories in this subsector are represented with a delay function reflecting the wheat flour industry's storage and processing operations. Considering also grain inventories in import pipelines, the GMP model

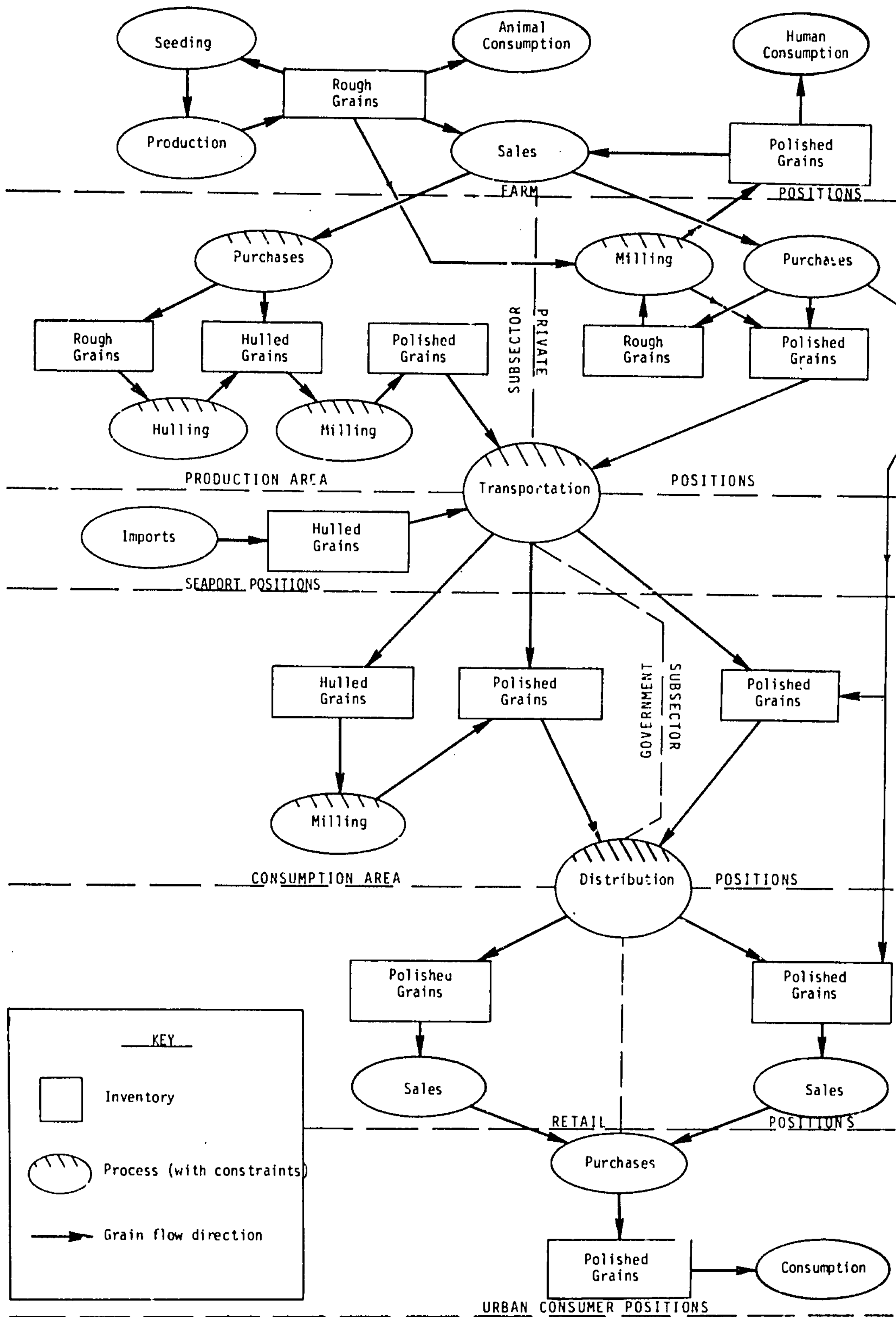

Figure 4. GMP Grain Flows and Storage

identifies food grain inventories at 20 distinct positions. In this section we describe some of the modeling techniques used to simulate the processes involved in managing these inventories.

It is not the purpose of this discussion to give full service to all the particulars of the GMP model design. The reader should note that each individual inventory of the GMP model is handled somewhat differently to best replicate what is actually occurring in the real world system. The general discussion given in this section best fits the inventory management processes of the private and government marketing subsectors. Decision processes for farm, urban, and wheat flour industrial sectors are somewhat different but similar enough not to be separately detailed.

Figure 5 can be a useful aid in describing the basic concept behind the design of position point inventory management of the private and government subsector models. Note that the figure is general in that not all, nor any particular position point, inventory is depicted. The three inventories, called I, II, and III, represent position point inventories along market channels. A basic assumption of the model is that food grains proceed through the market channels in a nonreversible manner. For example, grains do not flow from consumption area sales store positions back to mills located in production areas. In the figure this one-way flow of grains is assumed to be in the order of positions I, II, and III, progressively. The management strategy depicted in the figure is for position II. Other position point inventory management strategies would appear similar.

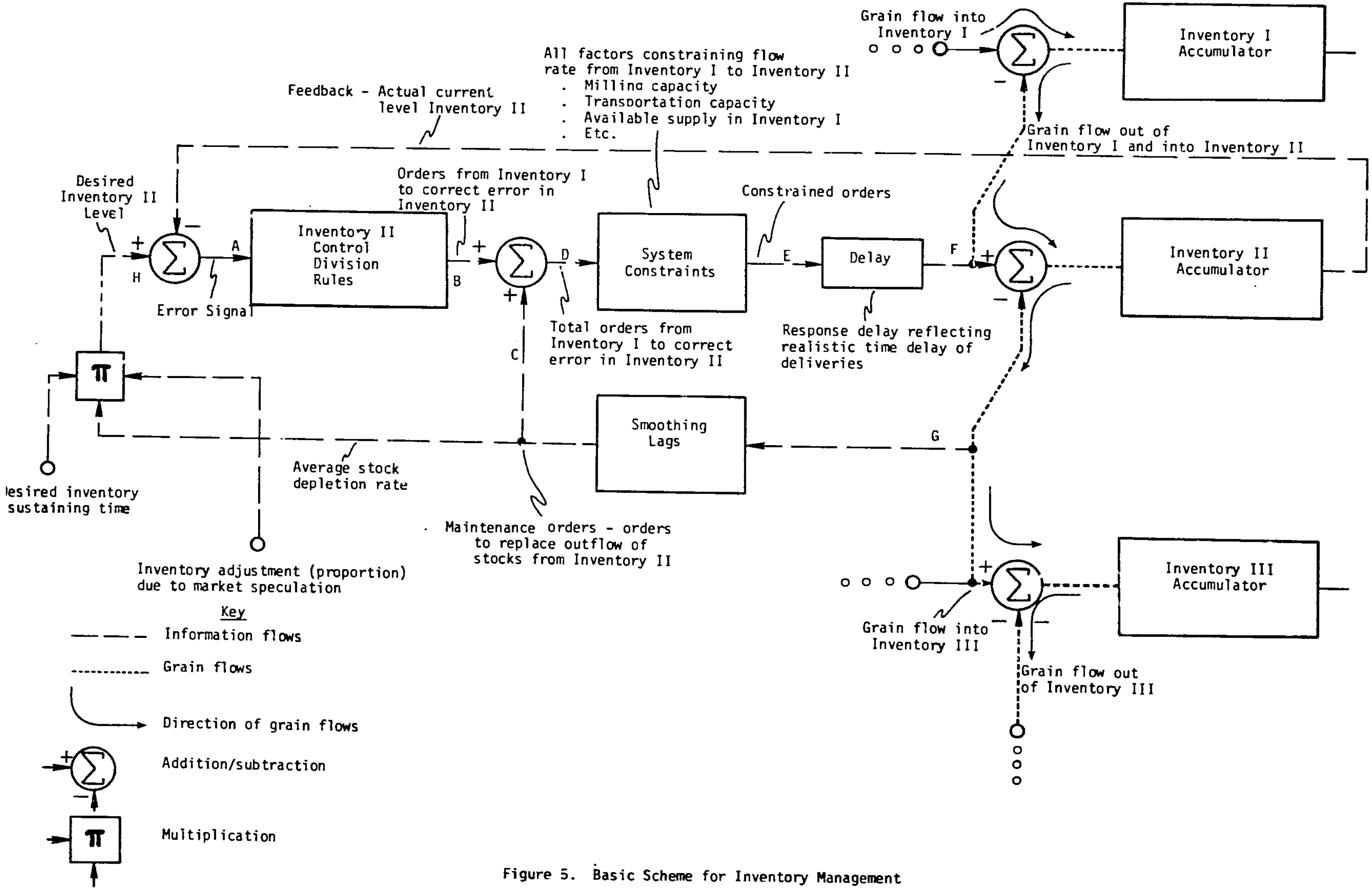

Figure 5. Basic Scheme for Inventory Management

Automatic feedback control techniques are used to represent real world inventory management processes. Managers for inventories at position II in Figure 5 are aware of current inventory levels, depicted by the feedback information loop. This information on current inventory level is compared with an ideal pattern of inventory level for this position. When a discrepancy is observed between actual and desired inventory levels for this position, corrective action is undertaken. However, many constraints and limitations exist in the real world system which can affect how much and what type of corrective action can be undertaken. A "pull-forward" concept of grain flows seems to best represent real world phenomena. This is to say, inventories at any particular position may be built by placing orders to preceeding position points. However, inventories may not be depleted by shipments to succeeding positions unless orders for shipments exist from those positions. This flow limitation concept is used to propagate urban consumer demand back through private marketing channels to the farm market.

Other constraints also exist. The rate at which orders can be filled for inventory position II depends on the system capacity to move stocks between positions I and II. This may involve milling capacity, if position I inventory is in rough form and position II inventory is in polished form. It may also involve transportation capacity, if position I is located in production areas and position II is located in consumption areas. Then, of course, stocks must be present at position I before orders can be filled for increasing position II inventories. Time delays are also involved in placing orders, grain handling, milling, transportation, and deliveries of grains to position II.[4]

Market Supply and Demand

We have described in general terms the movements and handling of grains within the GMP model. This degree of modeling effort and design is necessary to accurately represent the physical system constraints of grain movements between farm and urban consumer markets. We will now describe some of the important model functions that determine the supply and demand for grains that meet in the farm and urban marketplaces and are the primary factors in determining market prices.

Farm Supply

The supply of domestically produced grains on the market plays a vital role in market price behavior. Farmers' behavior in marketing their available supplies of food grains depends greatly on their credit situation, available stocks, and also on market prices which they can receive for thier products [9]. Government purchase prices and the timing of purchase programs also affect farm marketing behavior. These factors and others are combined in a set of farm marketing equations used in the GMP model. Farm marketing response has proven difficult to model (although acceptable results are being generated). Therefore, at this point it may be proper to mention an important aspect of the GMP model which lends it real strength; that is, the modularity of the model. Nothing in the model prevents the swapping in and out of various functions used to calculate behavioral characteristics, such production responses, consumption, or marketing behavior. The model is used with the best set of functions available at the time, with continual off-line work researching "better" or more up-to-date functions to use. As "better" functions become available, they can be inserted into the model and tested. If they test out, they can remain in the model until replaced, with little other effort involved. Therefore, in describing, say, the farm marketing behavioral response of the GMP model, it is preferred that we not discuss any particular function used in the model, for no function can be considered permanent--and no particular behavioral function should be constructed as representing the GMP model, for the model itself provides the structure and dynamic framework for testing behavioral functions which may be developed at a later date.

Urban Demand

Urban household demand in the marketplace is not taken directly from the human consumption function described in an earlier section. The GMP model also simulates the storage function of urban households so that effective urban demand in the marketplace represents urban household decisions to manage their home inventory stock levels. General price levels, price changes, and anticipated price levels all play a part in the urban household inventory management strategy.

Government Demand and Supply

Government demand and supply for food grains are policy variables representing specific grain management programs and objectives. The GMP model gives model users many opportunities to explore the use of these powerful instruments in dealing with several grain management problems. Much more will be said regarding government demand and supply of food grains in a later section of this chapter, dealing with the policy orientation of the GMP model.

Private Market Demand and Supply

The private market, acting as a major channel between farm and urban marketplaces, plays a vital role in the overall grain system. Market supply and demand functions generated in this subsector are the critical link between markets and play a critical role in influencing market prices. Unlike the government subsector, whose demand and supply functions are based on grain management program objectives, the private market subsector, as with any free enterprise, is motivated to act through the quest for profit.

The GMP model recognizes two possibilities for generating profits from private market activities. The *first* is by moving grains through the system and realizing a net profit margin between buying and selling price. Assuming that unit costs do not increase with volume, the more grain that can be moved through the system, the higher will be the total profits. The *second* potential means of generating profits available to the private marketing subsector is by purchasing grains on the farm market, holding them over time, and realizing a profit from increases in urban market prices. This second means of realizing profits, naturally has inherent speculative risks with it because of accumulating storage and interest costs over time and the uncertainty of urban market prices in the future.

The GMP model has a speculative behavior mechanism which forecasts future urban prices and demand available to the private marketing subsector. These forecasts are initialized at the beginning of each model run with empirical price and demand data from over the past several years.

As the simulation run progresses through time, model-generated data (prices and demands) are merged with initial past data, with the most recent data begin weighted heaviest. Seasonal patterns in data are recognized by the forecasting mechanism, with repeating or persistent seasonal patterns acting to reinforce confidence. The speculative response mechanism continually monitors current prices and forecasts and generates desired private market inventory levels through time, which (it thinks) can be held for a profit. Private market demand and supply functions of the GMP model reflect this speculative storage behavioral phenomenon.

Both marketing margin (flow) and market speculation (storage) incentives for generating profits are factors in the demand and supply functions of the private market. The flow component of demand and supply responds to changing margins between farm and urban market prices. As margins increase, the incentive to deal in more grains also increases; both the private market supply and demand increase. The effect of this is to increase farm prices (increased demand) and decrease urban prices (increased supply); thus, reducing the marketing margin. As margins decrease, the incentive to deal in grains also decreases; both private market supply and demand decrease. The effect of this is to decrease farm prices (decreased demand) and increase urban prices (decreased supply); thus, increasing the marketing margin. The net effect of the flow incentive factor is the influence it has upon maintaining normal farm and urban market price margins. The storage component of private market demand and supply does not affect marketing margins but has an amplifying effect on the market price changes. As urban price rises exceed the cost of holding grains, the storage incentive component acts to increase private market inventories. Increased demand and decreased supply act to amplify already rising urban prices (and increase farm prices as well). When storage is no longer foreseen as a feasible profit-making activity (e.g., when urban prices are falling), the storage incentive component acts to decrease excess private market inventories. Decreased demand and increased supply again have an amplifying effect on already decreasing urban prices (and act to decrease farm prices as well).

The relative influences of flow and storage incentives on total private market demand and supply, of course, are not known. The model-tuning process, however, enabled model designers to test various weighting factors for the two components. It is interesting to note that the model tuning process for rice indicated that in the farm market best results were gained by weighting the marketing margin (flow) responses much more heavily than the storage behavioral responses. However, in the urban market, best results were gained by attaching approximate equal weights of importance to the flow and storage responses. The logic of this phenomon is reasonable: merchants located in production areas, dealing in farm markets, are risking much more in holding grains on the basis of anticipated urban market price rises than merchants located in urban areas dealing directly with urban markets. This is due to the longer delay time required to market grains stored in production areas should the urban market suddenly begin to decline, as compared to those held, say, by commissioners or retail sales store merchants.

Market Prices

Farm and urban market prices are generated in the GMP model by bringing market supplies and demands for grains together mathematically. Basically, the price generation function describes the dynamic changes in market prices in response to disequalibriums of supply and demand over time. On the farm market, private market demand and government demand are combined and compared with the available farm supply. An excess market demand causes prices to rise, while an excess market supply causes prices to decline. On the urban market side, private market supply and government supply (releases) are combined and compared with urban demand. Again, an excess market demand causes prices to rise, while an excess market supply causes prices to fall.

The model recognizes the possibility that supply and demand from government and private subsectors may have different degrees of influence on market prices; that is, private demand may have a greater effect on farm prices than an equal amount of government demand, or vice versa. A similar assumption is made for urban market supplies from the two subsectors. One of the tasks in the model tuning process was to assign values to the relative importance of these two sources of market supply and demand.

Policy Orientation

In an earlier section of this chapter we listed several grain management program and policy issues for which the GMP model can be used to analyze and, hopefully, provide guidance and insight to researchers and decision makers concerned with real world grain management problems. The GMP model (and, for that matter, any simulation model) does not automatically become a useful analytical tool merely by being validated with respect to the real world system it is representing. Much thought and model design must be devoted to surface the important policy instruments and system variables under control of the eventual model user, making them apparent and readily accessible. Strict attention is necessary to assure that these policy instruments are *connected* in a realistic manner to the overall system.

The GMP model is designed for use by the government sector and is thus oriented toward addressing issues of interest to that sector. The same model conceivably could be oriented toward the interest of other decision makers in the system, such as farm cooperatives, the Private Millers Association, wholesale commissioners, or the Korean Flour Millers Industrial Association (KOFMIA). As such, the model would have a different policy (or use) orientation, with design emphasis on instruments in control of these model users.

It is difficult to clearly classify all types of grain management program and policy issues of interest, or potential interest, to the Korean government. About the best that can be done is to isolate some of the important ones into three categories. *First*, are problems in grain management policy and program development for planning and investigative purposes. Analyses in this category may be aimed at investigating the consequences (good and bad) of continuing current policies or changing policies to better meet current conditions. Basically, the model users are interested in asking "what if" types of questions of the model. These questions can be for periods in the past, as well as for periods into the future. For example, "what if" government policy on a particular issue, say, barley purchase price, had been different during the past crop season? What impacts would such a difference have on changing the behavior and performance of the grain system through time and up to its current state? Or "what if" barley purchase price policy were changed now? What would be the consequences of such an action compared with continuing past policy for, say, two years into the future?

A *second* category of problems which are of interest to government officials is problems in current policy administration. Here model users are interested in asking "how" types of questions. For example, planning studies may indicate a desirable seasonable price pattern for the upcoming year...or the President sets by decree limits on domestic grain prices. "How" should government release programs be adminstered to best meet these objectives? How much government grain will be needed? What about the timing and amounts of government grain release? What pricing should the government set on these release grains, and what about replenishing government grain stocks?

The *third* category of problems of potential interest can be referred to as crisis situations. Perhaps the world grain situation suddenly changes, world grain prices soar, and/or fuel prices jump. Or a recent drastic change in domestic grain policy is observed to have unanticipated bad effects. Model users who are contending with these situations may be asking "now what" types of questions. For example, world wheat prices begin to soar and the government (as in 1974) raises wheat flour price by some 60 percent. Wheat demand drops; but subsequently rice demand increases and domestic rice prices begin to rise, seemingly in an uncontrollable fashion. Now what should the government do? Should they pour huge amounts of government rice or mixed grains on the market to attempt to bring price into control? What combination of release prices should they seek? Should they lower flour prices and pay increased subsidies to flour millers? Should they increase barley releases, lower or increase barley prices, or should they undertake a combination of the above actions in dealing with the crisis?

A general description is in order of the design orientation of the GMP with respect to some specific policy and program issues of the first two categories mentioned above; namely, problems of grain policy planning (and development) and problems of administering existing grain management operations. It is hoped that the reader, after becoming familiar with some of what the model can do, will begin to see for himself how it can be used in complex grain crisis situations as a guide and analytical tool for government officials searching for cures.

Annual Food Plans

The utility of the GMP model as a grain management tool is greatly enhanced by including the capability of formulating alternative annual food (grain) plans and measuring the consequences of these plans in conjunction with seasonal grain management policies and programs. Basically, a food (grain) plan consists of estimates of food grain requirements and supplies for the upcoming year. Food grain requirements are estimated as the total of expected farm and nonfarm household food requirements; government use requirements for military, government institutions; prisons and relief; livestock feed requirements; seed requirements for the next planting season; and requirements for food processing and industrial use. Expected waste and losses are also accounted in the total requirement estimate. Food grain supplies are estimated as the total of expected production for the upcoming crop year, plus carry-in--*plus* programmed imports which are given values to equate supplies with expected requirements.

A number of ways can be taken in arriving at estimates of household food grain requirements, depending on the issues at hand. For example, relative world market prices may be such that grain management officials responsible for developing a particular food (grain) plan may desire to change the diet mix of food grains (rice, barley, and wheat) to economize on foreign exchange expenditures for food grain imports. Self-sufficiency goals for certain food grain commodities may be important issues concerning officials formulating a food plan. In deciding on a zero import requirement for these commodities, officials developing the food plan must be reasonably confident that domestic supplies are adequate to support normal consumption levels over the period of self-sufficiency and/or supplies of substitute grains are planned adequately to preclude drastic price increases in the "self-sufficient" commodities. Socially tolerable limits of consumption pattern shifts to less preferred food grains must also be considered from a political standpoint. Basic food grain price structure may also be of primary concern, since food grains likely play a dominant role in the consumer price index. In short, formulating a typical food plan requires keen concern over economic, social, and political implications.

<u>Generalized Demand-Price Analyzer</u>

Government officials engaged in formulating a basic annual food (grain) plan are concerned with both quantities and prices of food grains for the upcoming planning period. The generalized demand-price analyzer (a derivation of which is detailed in Chapter 17) enables the model user to specify a mix of prices and/or demands for food grains for a particular food plan. The model then uses linear algebraic techniques to solve for the unspecified prices and/or demands, with the result being a full set of annual average food grain prices and demands which are consistent with the Korean food grain demand system specified in the model.

If a specific food (grain) plan requires that domestic supplies be supplemented by imports, the government must import the required amount of grains during the upcoming year and assure that they are available (and in the right amounts) when needed. Such a plan also will require basic (annual) food grain price levels and relationships during the upcoming year to realize the planned consumption levels of rural and urban populations. The government will have to monitor prices throughout the year and administer its domestic grain operations to assure that these annual price levels are met. The GMP model can provide guidelines into these (and other) types of operating and management problems.

Seasonal Price Policies

Establishment of annual food plans and appropriate importation of deficit food grain commodities by government will not assure domestic seasonal price stability. Domestic food grain prices may vary widely during the year, depending on available market supplies. These variations, if too large, can have adverse effects on both farm and urban populations, especially the lower income groups. To assure seasonal price stability in domestic food grain prices, it may become necessary for the government to monitor current market conditions and play an active role in domestic grain dealings (buying and selling).

Seasonal price policy objectives may vary from striving to keep domestic prices within tolerable bounds to targeting prices to follow precise seasonal patterns. Choosing a desirable seasonal price policy (or a *set* of seasonal price policies for the different food grains) is important in influencing the overall grain system to operate in a desirable manner [7]. Various seasonal price patterns can influence farm consumption behavior, farm storage and marketing behavior, farm income from grains and the amount of domestic grains made available for urban consumption. Price patterns also affect the storage and marketing behavior of the private marketing subsector (complementary to government marketing activities). Given proper price incentives, the private subsector can be motivated to function as an effective grain storage and distribution system for moving and processing large amounts of domestic grains over time from farmers to urban consumers.

The GMP model can be used to investigate impacts of various seasonal grain price policies on the performance of the overall grain system.

Just how the GMP model can be used to guide the actions of the government to assure that domestic food grain prices behave in a prescribed manner will be discussed below.

Seasonal Price Control

Given seasonal price objectives, government officials must closely monitor market prices and order appropriate government market activities when prices begin to stray from the desired patterns. Information on current market prices is often delayed in getting to decision makers. This information may have inherent measurement errors, due to imperfect market surveys, human errors in compiling vast amounts of data, etc. Faced with this information, government officials must act in ordering the next day's grain releases or scheduling grain releases over, say, the next week. Normally the analytical tools available to these government officials are few, if they exist at all. Mostly, these decisions are made based on hand calculation, past experience, and human intuition. Some officials may become quite skilled at ordering government grain releases in the appropriate amounts and in a timely manner to control urban food grain prices. Others may miss early signals of impending trouble and delay releases or not release appropriate amounts to head off market price rises. Suddenly, prices may be soaring out of control, requiring huge amounts of government releases to bring them down again.

The seasonal price control mechanism developed for the GMP model simulates the decision processes involved in attempting to control market prices to prespecified targets. Automatic feedback control techniques are used to monitor current market prices, to compare these prices with desired price patterns, and to generate corrective government grain activities (buying and/or selling) to influence market prices to follow desired seasonal patterns.

Figure 6 depicts the basic design of the price control mechanism developed for the GMP model. Important points along the figure are lettered to assist the following narrative description. Point A of Figure 6 identifies the desired seasonal price patterns which are reference inputs to the price control mechanism. These price patterns represent what grain management decision makers feel would produce the "most desirable" grain system response in meeting the objectives of seasonal price policies. Several alternative seasonal price patterns can be tested with the model arriving at a "most desirable" pattern.

Point B identifies the error signals which are produced by comparing desired price patterns with information on actual price patterns produced by the simulation model.

Point C identifies the prescribed government buying and selling activities produced by applying specific decision rules to error signals represented at point B. These decision rules are developed by model designers, using system control theory and a process of trial and error, until the resulting prescriptions produce the most acceptable system responses.[5]

Point D identifies food grain prices produced by the GMP simulation model with the government undertaking the actions prescribed at point C. These model prices are then fed back into the price control mechanism

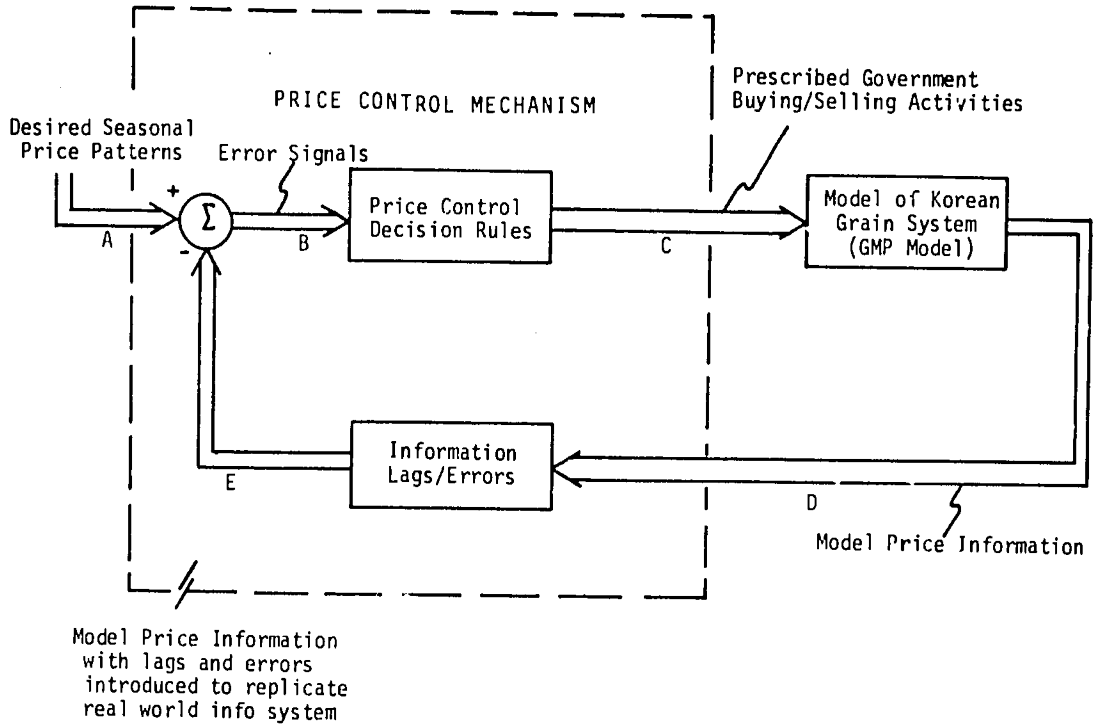

Figure 6. Seasonal Price Control Mechanism

for comparison with desired price patterns. Note that an attempt is made to replicate information lags and errors in observing market prices (point E). This is done to effect a control design more apr.icable to the real world situation.

In utilizing the GMP model for determining actual goverment buying and selling activities required to control market prices, the following approach might be taken:

1) The GMP simulation model would be initialized as closely as possible to the current real world situation. This would include current food grain price levels, rates of change of prices, system inventory levels, current urban consumption demand, and other states of the real world system which are reflected in the model.

2) The model would then be run over a desired time horizon, say, one year, to determine a tentative schedule of government grain activities (e.g., the amounts and timing of government grain releases) required to control (urban) food grain prices to desired patterns.

3) The schedule of government grain activities derived in step 2 is then used for the basic planned scheduling for government grain releases. As time evolves, real world prices will almost certainly deviate from the desired patterns. This error would be due to model errors, measurement error in the real world, incomplete model specification and random disturbances which affect the real world system.

4) To compensate for the price deviations observed in step 3, a corrective action release schedule is determined, again using the system model. This time the error signals observed in the real world are input to the model price control mechanism. These prescribed

corrective action releases are then superimposed on the original basic plan for government grain releases.

5) The above process would be repeated as frequently as necessary to keep the model prescriptions well in line with the real world situation.

Foreign Grain Import Scheduling

The annual food plan mechanism described earlier can be used to approximate the level of foreign grain imports necessary to keep annual price levels in line with price policy objectives. Scheduling of foreign grain imports, however, is an important decision process which can be very costly if not managed properly. Foreign grains which arrive in-country during times of high inventory levels require prolonged storage times or increase the storage time requirements of existing government stocks. For reasons of national security and to assure a equate buffer stocks for seasonal price stabilization, it is also necessary for the government to maintain reserve grain stock levels at some minimum level.

The GMP model can be used to determine import scheduling required to assure that government reserve stock levels do not dwindle below minimum acceptable levels, regardless of government release (and domestic purchasing) programs designed for seasonal price control. The mechanism used in the model utilizes automatic feedback control techniques in much the same matter that they are used for controlling domestic position point inventories. Government stock levels are monitored by the model and compared to minimum reserve stock level requirements.

When stock levels are observed to be approaching minimum acceptable levels, new import orders are commanded. The intensity and timing of these orders are attuned with current government domestic purchase and release activities, and compensate for lag times between import orders and deliveries.

Government Purchase Programs

In carrying on government price stabilization (and control) programs, it is necessary for the government to play an active role in the domestic grain markets. We have described the important aspects of the seasonal price control mechanism of the GMP for controlling urban food grain prices through government grain releases. The government also has an influence on farm market price behavior through its grain release programs, because urban and farm market prices are *connected* in the real world system as well as in the GMP model. However, no attempt is made in the model (or in the real world) to influence farm prices in any predetermined manner through government releases. A more direct linkage with farm market prices is gained through government purchase programs. Korea does not have an active program for controlling farm prices, as the government purchasing programs always occur during and immediately following the harvest season. The primary objective of these programs is to replenish government grain stocks from domestic supplies. One of the resulting consequences of the increased demand after harvest due to these purchasing programs is to dampen farm price declines after harvested that normally occur. This is considered a "good" result of purchase programs but not a primarily motive for the programs.

The GMP price controller is designed to prescribe both government purchase and release patterns necessary for controlling either or both farm and urban prices to prespecified seasonal targets. Variations to current purchasing programs can also be investigated by the model, without strict farm price control as the primary objective. Programs of extended buying periods, and/or increasing government buying price throughout the buying period to motivate farmers to store their grains longer before marketing, can be investigated [7].

Government Grain Management Procedures

Another group of policy issues for which the GMP model is design oriented are questions of management procedures used on government-controlled grains. The government traditionally purchases paddy rice from farmers since the paddy form increases storability. However, storage space requirements of paddy rice, being approximately twice that of brown rice (hulled rice), oftentimes puts a critical strain on existing storage facilities. Overflows are often piled out-of-doors, or placed in very inadequate storage facilities and are subject to high losses. Solutions to such problems are usually prescribed as construction of additional goverment warehouse capacity. Alternatives to the construction solution exist, and the design of the GMP model is oriented to allow for the study of several of these alternatives. For example, to take the pressure off of government storage facilities, a portion of government domestic rice purchases could be taken in brown (hulled) form. These grains would require one-half the storage space of paddy form, and could be milled and moved onto the market before government grains stored in rough form, to reduce storage requirements. Another management alternative for government grains may be to hull government rice in production areas in amounts necessary to eliminate inventory overflows and then to re-store it in brown rice form. When needed in consumption areas it could be milled in production areas or moved into consumption areas in brown rice form and milled there in government-licensed mills normally operating only in imported grains. Additional handling costs are, of course, inherent in such alternatives to grain management procedures. The feasibility of such activities versus construction of additional warehouse facilities, or simply letting overflows occur during peak periods, would require very detailed investigation. The GMP model is designed to aid in such studies.

Government Warehouse Construction Programs

This aspect of the GMP model has less significance when the model is used for short-term policy issues, say, one to two years. However, when using the GMP model for addressing longer term policy issues or running the model in conjunction with the Korean Agricultural Simulation Model (KASM), government warehousing programs may have major implications in grain management policy formulation. Specific warehousing construction programs may themselves be the central issue in a particular grain management program study. In such instances, this component of the GMP model stands able to provide important information to researchers and decision makers.

Government-owned or -leased warehousing facilities are classified into five major categories: (1) low-temperature, (2) Class A, (3) Class B, (4) Class C, and (5) Auxiliary storage. These categories are based on construction design and suitability for grain storage, with the Low-temperature facilities being most elaborate and Class C and Auxiliary being least elaborate, usually deteriorated in condition and least suitable for grain storage. Each of these warehouse classifications has inherent different unit construction costs (or storage charges, if not owned by the government) and storage loss characteristics over the four seasons of the year. Government warehouse construction programs can build additional warehouse facilities in the first three categories (Low-temperature, Class A, and Class B), but not in the latter two (Class C and Auxiliary). As the process goes, Class A and Class B facilities can depreciate to lower categories as time evolves.

The government warehousing component allows for government construction programs in each of the first three categories and a choice of construction location in seaports, production areas, or consumption areas. The model then monitors the amount, distribution, and location of government warehousing facilities through time, based on new construction programs (if they exist), the normal declassification process of A and B facilities, and the salvage and disappearance of Class C and Auxiliary.

The government warehousing component is also linked with the government grain operations model. That is, the position-point storage capacities and loss rates applied to government grain inventories of the government operations model are consistent with the government warehousing component.

System Performance

The third and final category of the GMP model design is system performance. Model design under this category is perhaps not as difficult as modeling the operational grain system and orienting the model to address real world problems, but it is certainly just as important. Without meaningful measurement of system performance, model users have neither the means for judging among alternative grain management policies nor analyzing the results of model runs. Careful attention must be given to the design of system performance measurements to assure that they are consistent with model user needs. These needs are best defined by potential model users themselves (i.e., policy analysts and decision makers); therefore, much interaction is required between these people and model designers.

Several types of system performance measurements can be output from the GMP model. Information can be presented in a form and in the units requested by model users.

Forms of Model Output

Regardless of what information is made available from a simulation run, it is always helpful to have an option of viewing the information in several forms. Specially designed summary tables are one option for viewing results of GMP model runs. Although the model simulates the operations (and measures performance) of the grain system through time, model users are often concerned about summary information describing system performance over a period of time. Users of the GMP model have the option of defining the periods for which summary tables are output, as well as which tables are output. In analyzing model results, however, oftentimes it is helpful (and necessary) to know the time paths actually traveled by particular system variables. The GMP model gives the user the opportunity of viewing any set of model variables (including performance criteria) in time series form. These series can be output in tabular and/or plot form, depending on the reouest of the user. The user can also specify which variables appear together on the time-series plots and/or tables.

Operations Performance

Table 4 summarizes some of the important system operation performance measurements available to model users. Time series of these variables have a one-to-one correspondence with variables generated in the grain system operations model, although the user has an option of specifying the interval at which the time series are output. Summary tables present information about the performance of model time series variables in a number of ways. For example, average values for some variables, such as prices, inventories, and consumption rates, are calculated and presented in summary tables. Maximum and minimum values attained by time series variables are also presented where such information is deemed necessary. Even the calendar dates of when maximums and minimums are observed to occur are printed in various summary tables which are available to model users. Many other system performance variables not indicated in the table are also available.

Table 4. Grain System Performance--Operations

Variable	Unit	Farm		Urban		Private		Government		Total Systems	
		Time Series	Summary Tables	Time Series	Summary Tables	Time Series	Summary Tables	Time Series	Summary Tables	Time Series	Summary Tables
Production	MT/yr	X									
	MT		X								
Imports	MT/yr					X		X		X	
	MT						X		X		X
Sales	MT/yr	X				X		X			
	MT		X				X		X		
Purchases	MT/yr			X		X		X			
	MT				X		X		X		
Consumption	kg/cap/yr	X	X	X	X						
	MT/yr	X	X	X	X						
	MT		X		X						
<u>Inventories</u>	MT	X	X	X	X	X	X	X	X	X	X
By Form	MT	X				X		X			
By Position	MT	X	X	X	X	X	X	X	X	X	X
Carry-overs	MT		x		x		X		X		X
Stock changes	MT		X		X		X		X		X
Processing	MT/yr					X		X			
	MT						X		X		
Population	people	X	X	X	X						
Prices	won/bag	X	X	X	X						

Accounting

The GMP model provides detailed cash flow analyses for all subsectors. Such information is very important performance criteria in analyzing various grain management problems. Table 5 summarizes some of the important accounting data provided by the GMP model.

Special Criteria

Depending on the issues at hand, special performance criteria can be measured and presented to model users to assist them in determining the consequences of particular grain management programs and policies. For example, use of the model in determining the effects of critical food grain shortages (brought about by a hypothetical world crop failure, warfare, or any other reason) and developing plans for dealing with such a crisis situation may raise questions regarding nutrition levels, nutritional deficits, and even death rates from starvation. Other uses of the model, say, to determine the effects of radical changes in grain management policy, may ask for measurement of such things as "discount." Changes from normal diet levels or diet mixes of food grains are possible measurements which can be made to generate these types of performance indices. Model users working with technicians can develop any number of special criteria to be used in analyzing model results. The GMP model has the capability of producing several special performance criteria of the type mentioned above.

Model Performance

To this point we have described some of the important information furnished by the GMP model regarding the performance of the *simulated*

Table 5. Grain System Performance--Accounting

Variable	Unit	Farm		Urban		Private		Government	
		Cash Flow	Summary Tables	Cash Flow	Summary Tables	Cash Flow	Summary Tables	Cash Flow	Summary Tables
REVENUES									
Grain Sales	won/yr	X				X		X	
	won		X				X		X
--Product Sales	won/yr					X		X	
	won						X		X
--By-Product Sales	won/yr					X		X	
	won						X		X
Value of Grain Consumption	won		X						
EXPENDITURES									
Domestic Production Cost	won/yr	X							
	won		X						
Grain Purchases	won/yr			X		X		X	
	won				X		X		X
	won/HH				X				
Grain Operations	won/yr					X		X	
	won						X		X
--Processing	won/yr	X				X		X	
	won		X				X		X
--Handling	won/yr					X		X	
	won						X		X
--Storage	won/yr					X		X	
	won						X		X
--Credit	won/yr	X				X		X	
	won		X				X		X
Foreign Exchange (Imports)	won/yr							X	
	won								X
Payments to Principle and Interest (Imports)	won/yr					X		X	
	won						X		X
Subsidy Payments	won/yr							X	
	won								X
Warehouse Construction	won/yr							X	
	won								X
Administration	won/yr							X	
	won								X
CASH FLOW ANALYSIS									
Gross Returns	won/yr	X				X		X	
	won		X				X		X
Value of Stock Level Changes	won		X				X		X
Net Returns	won/yr	X				X		X	
	won		X				X		X
	won/HH		X						

system. The model also monitors its own performance. When using the model to investigate various seasonal price stabilization or control strategies, the user is furnished with summary information on how well these strategies actually work to influence (simulated) market prices to move along targeted seasonal patterns. Many comparisons between targeted and resulting price patterns are made. Some of these comparisons are shown below:

Price Measurement	Unit	Target	Results
Average	won/bag	-	-
High	"	-	-
Low	"	-	-
High/Low Ratio	no unit	-	-
Maximum Rise	percentage/yr	-	-
Maximum Fall	"	-	-
Average Trend	"	-	-
Coefficient of Variation	no unit	-	-

The model also maintains a data bank of important grain statistics from past years. This bank is used for two major purposes: (1) model testing and tuning, and (2) automatic model initialization.

Designers of the GMP model realize that if the GMP model is to gain and maintain credibility as a viable grain management analytical tool, it must be under continual scrutiny and testing to improve its performance and keep it attuned to the changing real world [15]. The GMP data bank provides model designers and users with automatic access to important grain statistics needed to determine how accurately the model can reproduce past data. Users can compare time series data from tables or plots on which empirical data are overlayed on model-generated data of the same variable. The model also can provide statistical information on fits between model-generated and statistical data, such as sum of least squares, coefficients of determination (R^2), and B-coefficients, which regress model results on empirical data.

The data bank also serves for automatic model initialization at any time point in the past for which data are present. The GMP data bank currently contains monthly and annual statistical data from 1966 through the later part of 1976. Table 6 indicates some of the specific time series present in the GMP data bank. Maintenance of this bank with current and accurate information is crucial if the model is to serve its role as a grain management tool, "ready" to provide timely and valid analyses of current grain management problems.

A Sample of GMP Model Testing and Results

Many words have already been spent in describing the basic concept of the GMP, indicating some of the procedures used in its design and, hopefully, giving the reader some appreciation for the wide range of potential uses that can be made of the GMP model. In order to accomplish this overall perspective of the model, it has been necessary (for the most part) to remain in the abstract and discuss the model in very general terms. With this background, it seems the intent of this chapter can now be fulfilled by providing the reader with a sample of some specific model testing and results.

Setting for the Example

In this example of GMP model results we limit ourselves to two runs of the model. Both runs serve to demonstrate the kinds of credibility testing (see Chapter 1) to which the GMP model is constantly subjected.

Table 6. GMP Data Bank for Model Initialization, Historical Tracking, and Grain Policy Analysis (December 1976)

Series Description	Unit	Period of Data (Year.Month)		Data Points
		Start	End	
Monthly Prices Received by Farmers (Polished Equivalent)				
Rice	won/80 kg	66.1	76.8	128
Barley	won/76.5 kg	66.1	76.8	128
Wheat	won/76 kg	66.1	76.8	128
Monthly Consumer Prices (Seoul)				
Rice	won/80 kg	66.1	76.9	129
Barley	won/76.5 kg	66.1	76.9	129
Wheat flour	won/22 kg	66.1	76.9	129
Government Purchase Prices				
Rice	won/80 kg	1965	1976	12
Barley	won/76.5 kg	1965	1976	12
Government Release Prices by Month				
Rice	won/80 kg	66.1	76.9	129
Barley	won/76.5 kg	66.1	76.9	129
Monthly Price Indices				
Consumer Price Index (excluding cereals)	(1970=1)	66.1	76.9	129
Wholesale Price Index (Excluding Grains)	(1970=1)	66.1	76.9	129
Monthly Consumption				
Rice (Farm)	kg/cap/yr	66.1	76.8	128
(Urban)	"	66.1	76.8	128
Barley (Farm)	"	66.1	76.8	128
(Urban)	"	66.1	76.8	128
Wheat (National)	"	66.1	76.7	127
Monthly Inventories				
Rice (Farm)	MT	66.1	76.8	128
(Government)	"	66.1	76.10	130
(Urban)	"	66.1	76.8	128
Barley (Farm)	"	66.1	76.8	128
(Government)	"	66.1	76.10	130
(Urban)	"	66.1	76.8	128
Wheat (National)	"	66.1	76.7	127
Monthly Farm Sales				
Rice	MT/mo.	66.1	75.9	117
Barley	MT/mo.	66.1	75.5	113
Monthly Government Purchases				
Rice	MT/mo.	66.1	76.10	130
Barley	MT/mo.	66.1	76.12	132
Monthly Import Arrivals				
Rice	MT/mo.	66.1	76.9	129
Barley	MT/mo.	66.1	76.9	129
Wheat	MT/mo.	66.1	76.9	129
TOTAL				3,855

The time period under investigation for both runs is the three-year period beginning 1 January 1974 and ending 31 December 1976. Although this is now an historical period, the reader should note that absolutely no information regarding market prices, consumption rates, or any other endogenous model variables beyond the initial starting conditions on 1 January 1974 have been provided to the model. This includes model parameter estimates such as consumption elasticities which were based on time series data available before 1974.

Historical Tracking

The first run tests the GMP model's ability to replicate the real world grain system operations and provides a base to which other run results can be compared. The model is initialized (automatically) at the beginning of the run from data pulled from the data bank representing consumption levels, market prices, food grain stock levels, etc., prevailing on 1 January 1974. The model then proceeds to step through time, calculating all system variables at increments of 1/200 yr (1.8 day) intervals for three years. Government policies and grain activities such as buying and release prices, imports, domestic purchases and releases are input to the model from the data bank and represent actual real world values (according to available data) for these variables throughout the model run.[6]

Grain Management Policy Alternative

Judging from what has already been said about the scope of the GMP model for investigating a wide range of grain management issues, the reader should realize that it is impossible to demonstrate all aspects of the model in a single alternative run. We choose here a very simple example:

> Suppose the government wishes to investigate the consequences (goods and bads) of undertaking an active urban rice price control program to attempt to influence urban rice price to move along a prespecified seasonal pattern. The government also requires some prescriptive guidelines as to just how it should manage its release program to achieve this seasonal price pattern. To sweeten the example a little further, suppose the government also undertakes an import policy to replenish its stocks of rice from foreign imports only to the extent of maintaining its rice stock levels at a minimum of 400,000 metric tons. The government requires guidelines for scheduling import orders to maintain this minimum stock level.

For a sound comparison between model results of the baseline run and this policy alternative run, all other government policies and grain activities (other than rice releases and imports) are identical in the two runs; government purchase programs remain the same, and government buying and release prices remain the same.

Historical Tracking Results

Figures 7 thru 10 illustrate a limited set of the system time series variables generated in the baseline (historical tracking) run of the model.[7] Data from the GMP data bank are plotted along with model generated variables so that the reader has a clear view of just how well the model performed during this test run. Tracking performance is also measured quantitatively through the use of various statistical measurements (see Table 7). Figure 7 illustrates the consumption of rice and barley by the farm population. These series were chosen to demonstrate the ability of the model to represent the substitution effect between rice and barley consumption, especially in the farm population where it is normally more prevalent. Although these results appear good, other tests of the model indicate the consumption behavior equations used in the model perform much better when provided actual farm and urban market price. The reader must recall that these functions are driven by model generated prices.

Figure 8 illustrates government rice inventories, modeled and actual, throughout the period of the baseline run. Other system inventories such as farm, private market and urban household inventories could also be illustrated but are not in order to simplify the illustration. The seemingly poor performance of the model in reproducing government inventories during the period actually points out another potentially useful aspect of the model--data consistency verification. In this run, all government grain activities were input from historical data, i.e., government purchases, government releases, and imports. The government rice inventory level generated is merely an accounting of government grain accumulations from this data, indicating an inconsistency in official government data--either in grain activities reported, inventory levels, or both.[8]

Figure 9 illustrates rice marketing activities during the period of the historical tracking run. Government rice purchases, releases, and imports are shown along with private market purchases and sales. Farm sales and urban purchases which equal the sum of government and private purchases and sales, respectively, could also be shown; but this would make the figure much too difficult to follow. The reader will later be asked to refer back to this figure to compare the changes in government grain activities (releases and imports) prescribed in the policy alternative run.

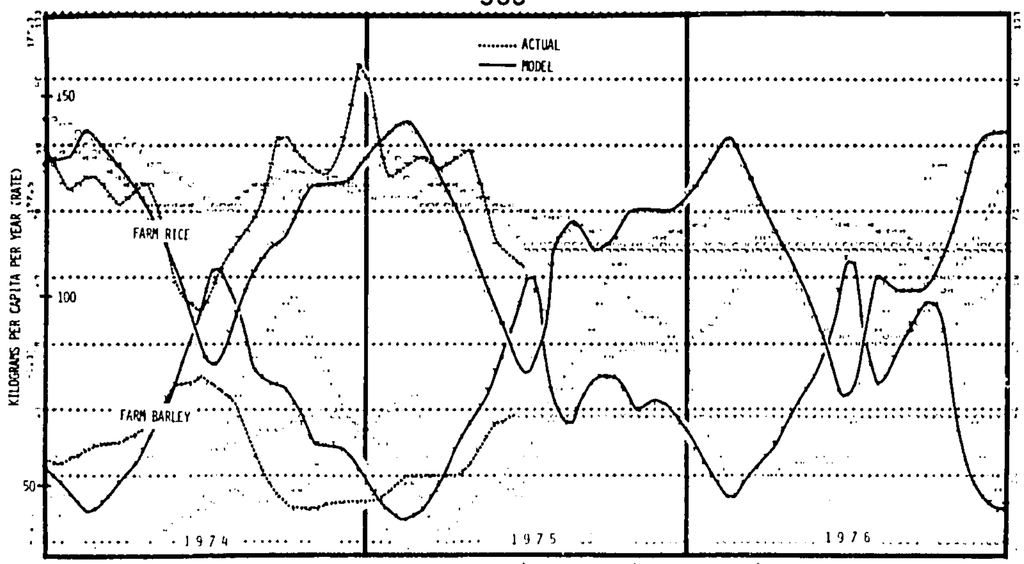

Figure 7. Food Grain Consumption Tracking

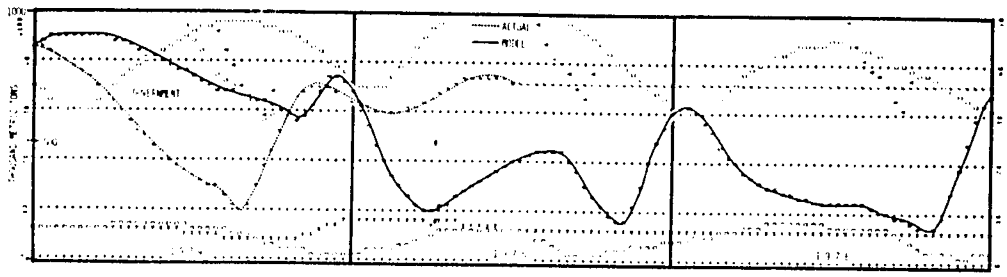

Figure 8. Rice Inventory Tracking

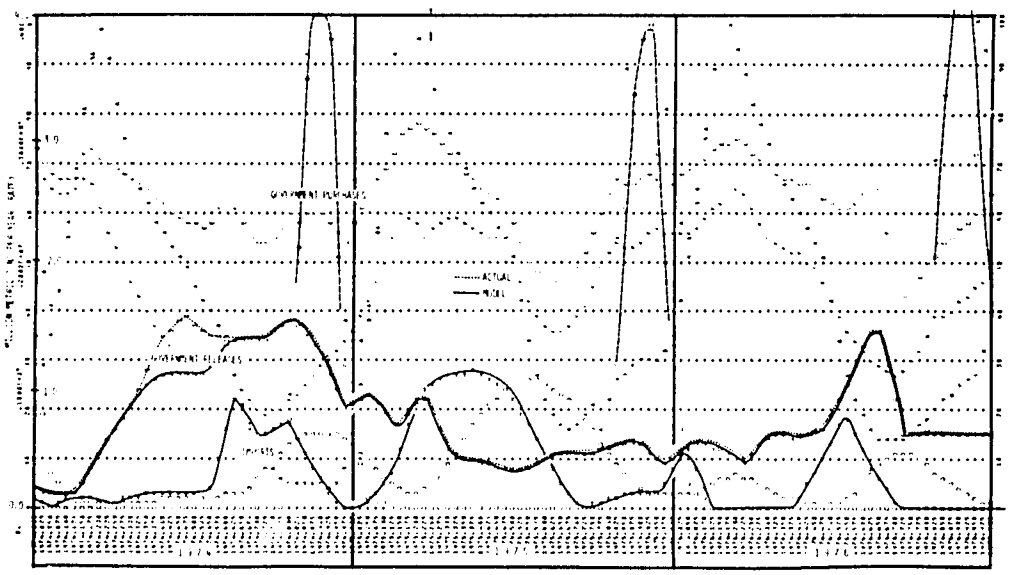

Figure 9. Rice Marketing Activities

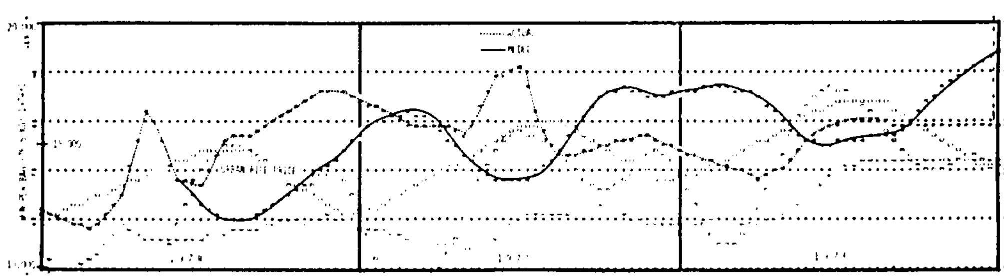

Figure 10. Urban Rice Price Tracking

Figure 10 illustrates the greatest challenge to the GMP model--simulating market prices. The figure displays actual vs. model urban market rice price during the period of the run.[9] These results represent the culmination of much hand-tuning of the model (the process of assigning values to model parameters affecting the pricing function). In all, close to ten major parameters (tuning knobs) are involved in the performance of the pricing functions. This is far too many parameters to adjust simultaneously by hand to achieve maximum model performance; like tuning an engine carborator with ten needle valves without the aid of a machine. Nevertheless, model designers are pleased with the level of performance indicated. Model prices are not bounded in any way, precluding the situation present in many simulation models where model variables, more often than not, *ride the bounds*. Hand tuning of the pricing function indicates that the GMP has the parameters and model construct to alter the behavior of the pricing functions in virtually any conceivable manner. All that is needed is some automated assistance in finding the proper value of these parameters to maximize model performance. Computerized optimization packages suitable for such tasks are available and can be applied to efficiently explore the parameter space of the model to attain (undoubtedly) much more accuracy [1].

As mentioned in an earlier section, the GMP model provides various measurements of its own performance in tracking key variables. Some of these measurements are given in Table 7 for the key variables discussed above and others not discussed.

Table 7. Historical Tracking Performance

Key Variable	Rice			Barley[a/]		
	Measurement of Performance			Measurement of Performance		
	SSE[b/]	B-coef[c/]	R^2 [d/]	SSE	B-coef	R^2
Farm price	.255 (12%)	1.88	.325	.248 (12%)	.231	.082
Urban price	.213 (11%)	.409	.385	.212 (11%)	-.333	-.467
Farm consumption	.271 (12%)	.517	.522	.593 (18%)	.412	.091
Urban consumption	.037 (5%)	.359	.388	.534 (17%)	.283	.628
Farm inventories	.113 (8%)	.994	.975	1.509 (29%)	1.345	.895
Farm sales	NA[e/]	.800	.654	NA	.499	.387

a/ Poor performance in barley is indicated because most model-tuning effort at time of run had been devoted to rice. Much improvement in performance can be expected.

b/ Sum of square errors (number in parentheses is percent error).

c/ B-coefficient of regression equation when model results are regressed on actual data (should be one).

d/ Coefficient of determination with sign (should be one).

e/ Not available due to program error (bug).

Policy Alternative Results

We have now established a baseline for making judgments regarding the outcomes of alternative grain management policies. Although it has been made clearly evident that the model is far from perfect in accurately reproducing past grain system performance, it is important to note that whatever deficiencies the model has in the baseline run are also present in alternative runs. If the model has invalid initialization data, invalid input variables, or invalid accounting coefficients in the baseline run, then the same information and parameters are present in the second run. If these model deficiencies cause errors in model results, these errors should run in the same directions in both runs, tending to cancel when comparisons are made between run results.

Figures 11 thru 14 illustrate the same time series variables which were illustrated from the historical tracking (baseline) run. The reader is free to view the two sets of plots and make any comparisons he wishes. Of most interest, however, is to note the changes in government imports, government stock levels, and government releases of rice indicated between the two runs. Figure 14 illustrates the targeted seasonal urban rice price policy under investigation along with actual (simulated) urban rice price realized by undertaking the government releases indicated in Figure 13. The figure indicates that the strategy used in the model for observing actual and desired price behavior and issuing release orders was quite successful in achieving the desired results. This strategy will not be discussed here in detail except for one point: the reader's attention is called to the early

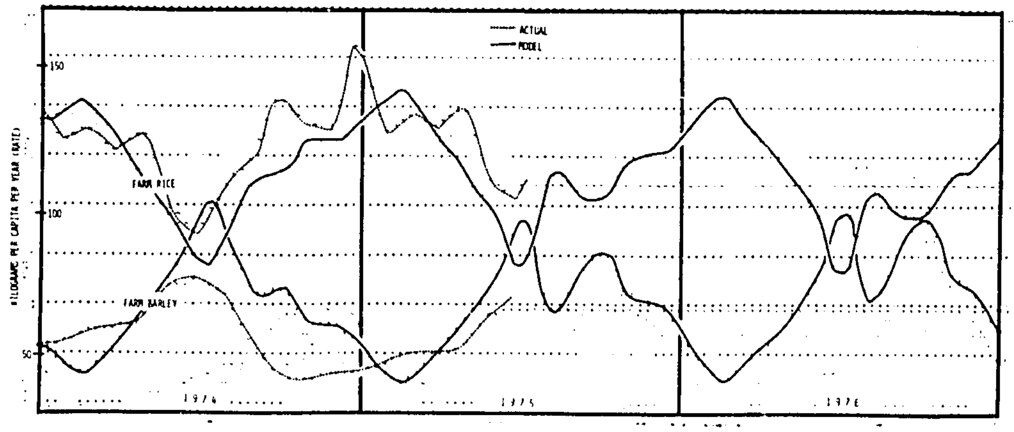

Figure 11. Food Grain Consumption Policy Alternative

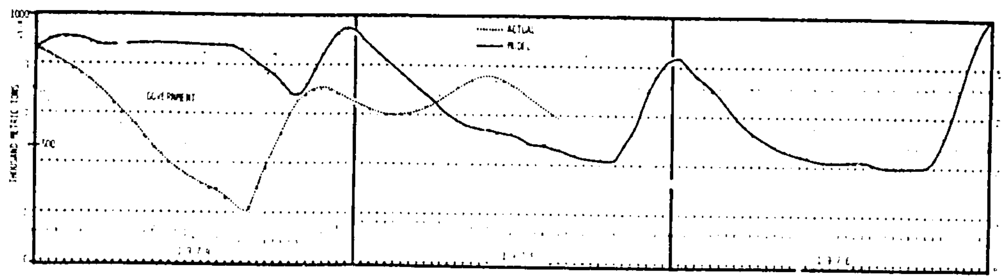

Figure 12. Rice Inventory Policy Alternative

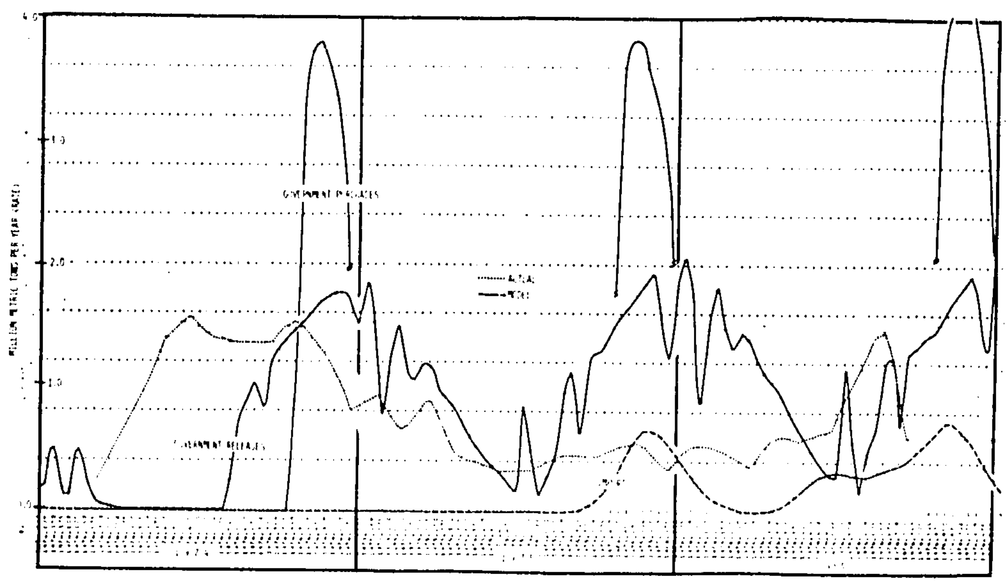

Figure 13. Marketing Activity Policy Alternative

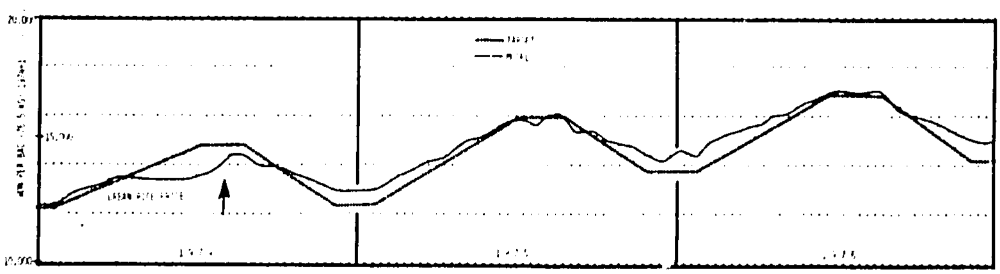

Figure 14. Urban Rice Price Control

warning capability of the urban rice price control strategy. Sizable government releases are called for long in advance of the time urban prices move above target levels. This can be seen by noting the position of the arrow on Figure 14 which indicates the time at which government releases are begun in order to turn urban prices downward.

Comparisons of Test Runs Results

Thus far we have presented some of the highlights of the results of both the baseline (historical tracking) run and the policy alternative (urban rice price-plus-rice import control) run. The plots and performance tables serve a useful purpose but give little information as to which of the two runs produced the *best* results. Many comparisons can be made to make this determination depending on the objectives of the grain management policy under consideration. Aftentimes both goods and bads will be indicated for particular policy alternatives under study, however, it is up to the decision maker to weigh these results and make the final determination.

The basic question here is this: Would Korea's food grain situation be better (or worse) off today if the government had undertaken the grain management policy alternative studied in the second run of the example? As has been done throughout this example, we must severely limit ourselves in the comparisons and analyses made between the two test runs under consideration.

Table 8 enables the reader to compare selected items, such as imports, farm commercial sales of food grains, government share in the market, food grain consumption, etc., between the two test runs.

Table 8. Comparison of Selected Items for Model Test Runs

Unit: 1000 metric tons or kg/cap/yr (where applicable)

Selected Items	Actual Data	Baseline Run Results	Policy Run Results	Actual Data	Baseline Run Results	Policy Run Results	Actual Data	Baseline Run Results	Policy Run Results
	CY 1975			CY 1975			CY 1976		
Imports	2[illegible]2	253	0	480	483	153	165	160	278
Farm Sales	1805	2192	2230	2095	2429	2294	NA	2497	2427
. Government	756	623	641	780	524	654	789	672	779
. Private	1049	1569	1589	1315	1905	1640	NA	1825	1648
Urban Purchases	2781	2534	2643	2567	2563	2585	2621	2395	2624
. Government	1092	937	572	484	523	1021	687	484	1160
. Private	1689	1597	2071	2083	2040	2564	1934	1911	1464
Human Consumption	4390	4180	4152	4354	4113	4215	4391	3962	4185
. Average per-capita	127	121	120	123	116	119	121	110	116
- Urban Consumption	2757	2617	2610	2567	2522	2619	2621	2427	2634
. Average per-capita	130	125	125	119	117	122	117	108	118
- Farm Consumption	1665	1563	1542	1787	1591	1596	1770	1535	1551
. Average per-capita	123	115	114	129	114	115	128	111	112

The table also provides information on actual data on these selected items for 1974, 1975 and 1976. Comparisons between actual data and baseline results will (with the other information already given) help to establish the level of credibility the reader wishes to give the model for this particular test. The table is fairly self-explanatory and will not be discussed here.

Table 9 presents the impact of both runs on a pseudo-grain management special account. Baseline, policy alternative, and a comparison of run results is given in the table for calendar years 1974, 1975, and 1976. The table gives an abbreviated analysis for 1974 and 1976, with a more detailed analysis given for 1975. Major line items in the table are (1) Revenues, (2) Expenditures and (3) Stock Changes. Net account changes are also indicated for each year and are simply revenues minus expenditures plus the value of stock changes. The table gives run results for rice, barley and wheat accounts. A total accounts column is also given. In 1974, the table states that the baseline run indicated a 94 billion won (approximately 235 million U.S. dollars) loss in total grain accounts. The policy alternative run indicated on 82 billion won loss in total grain accounts for 1974. Comparing these results, the table states that a 12 billion won savings was indicated in the policy alternative run for 1974. Summary results are also given for the three year time period of the test. Table 9 states that a 207 billion won (approximately 431 million U.S. dollars) savings was indicated in the policy alternative run results for three year period. A 212 billion won savings (under the policy alternative)

Table 9. Grain Management Special Accounts

Unit: Billion Won

Line Item	Baseline Run Results				Policy alternative Results				Comparison of Run Results			
	A Rice	B Barley	C Wheat	D Total	E Rice	F Barley	G Wheat	H Total	E-A Rice	F-B Barley	G-C Wheat	H-D Total
	Results for Calendar Year 1974 (Abbreviated Analysis)											
Revenues	141	43	-	184	93	43	-	136	-48	0	-	-48
Expenditures	172	50	61	283	139	51	61	251	-33	1	0	-32
Stock Changes[a]	-16	21	-	5	12	21	-	33	28	0	-	28
Account Changes	-47	14	-61	-94	-34	13	-61	-82	13	-1	-	12
	Results for Calendar Year 1975 (Detailed Analysis)											
Revenues	101	45	-	146	199	45	-	244	98	0	-	98
- by-product sales	1	2	-	3	1	2	-	3	0	0	0	0
- product sales	100	43	-	143	198	43	-	241	98	0	-	98
Expenditures	202	75	18	295	190	75	20	285	-12	0	2	-10
- domestic purchases	117	47	-	164	159	47	-	206	42	0	-	42
- foreign purchases	70	14	-	84	15	14	-	29	-55	0	-	-55
- subsidies[b]	-	-	18	18	-	-	20	20	-	-	2	2
- grain operations	15	14	-	29	16	14	-	30	1	0	-	1
(handling)	(11)	(10)	(-)	(21)	(13)	(10)	(-)	(23)	(2)	(0)	(-)	(2)
(processing)	(2)	(1)	(-)	(3)	(1)	(1)	(-)	(2)	(-1)	(0)	(-)	(-1)
(storage)	(2)	(3)	(-)	(5)	(2)	(3)	(-)	(5)	(0)	(0)	(-)	(0)
Stock Changes	-44	48	-	4	-23	48	-	25	21	0	-	21
Account Changes	-145	18	-18	-145	-14	18	-10	-16	131	0	-2	129
	Results for Calendar Year 1976 (Abbreviated Analysis)											
Revenues	114	35	-	149	269	35	-	304	155	0	-	155
Expenditures	45	74	10	129	287	76	10	373	242	2	0	244
Stock Changes	-113	12	-	-10	42	12	-	54	155	0	-	155
Account Changes	-44	-27	-10	-81	24	-29	-10	-15	68	-2	0	66
	Summary Results for 3-Year Period 1974-1976 (Abbreviated Analysis)											
Revenue	356	123	-	479	561	123	-	684	205	0	-	205
Expenditures	419	199	89	707	616	202	91	909	197	3	2	202
Stock Changes	-173	81	-	-92	31	81	-	112	204	0	-	204
Account Changes	-236	5	-89	-320	-24	2	-91	-113	212	-3	-2	207

[a]/Difference between opening and ending inventories valued at period-end prices.

[b]/Table does not reflect policy change in wheat subsidies made in early 1976.

is indicated in the rice account over the three year period, while barley and wheat accounts show a three and two billion won losses, respectively.

The saving in the rice account indicated in Table 9 are derived from two major sources: (1) delayed sales of government grains at increased prices and (2) differences in import levels and in changes of stock levels. Some overall savings are indicated in grain operations costs for the three year period but, as can be seen in the table, the policy alternative run actually resulted in greater grain operations cost in 1975.

Interpreting the Results

A very brief review of the comparisons between the two test runs has been given. Much more analysis of the results would be necessary to form a sound judgement if the model were being used in a real world decision process. Evidently, as indicated by the model, the government may have realized major savings between 1974 and 1976 by undergoing an import policy similar to the one studied in the policy alternative. Also indications are that the government may have been delinquent in making upward adjustments in rice release prices. These price increases are implied by the delayed releases which occurred after price increases were already in effect. The increased release prices did not seem to hinder the effect of government releases on urban rice price control.

The reader, no doubt, has begun forming his own opinions and questions regarding the results of this test example. If he were working with the GMP he would undoubtedly ask for more analysis, or alternative runs to help substantiate his interpretations and answer questions brought to light here. Such activity is what the GMP model is all about--releaving the user of the drudgery of calculation, while at the same time lending insight into the complexities of managing the food grain system.

FOOTNOTES

[1] For more background information on grain policy in Korea, see [5,7,8,15,16].

[2] Computer costs for a run of the GMP vary considerably depending on the length of run, size of simulation increment, amount of analysis and output required, the particular computer used, etc. The test runs described at the end of this chapter cost approximately $25 on the MSU Control Data 6500 computer. Cost in Korea on a CDC Cyber 70 would be somewhat less for the same runs.

[3] Production costs for Tongil varieties exceed traditional variety costs by about 20 percent. In 1974, Tongil yield was estimated to be 34 percent greater than traditional varieties, giving a positive influence on the diffusion process with 40 percent more area going into Tongil production in 1975 [13]. In 1972, however, Tongil yields suffered from bad weather conditions and exceeded ordinary yields by only 20 percent. This caused a negative effect on the diffusion process with Tongil area declining by 26 percent in 1973.

[4] Although Figure 5 is fairly well annotated, a brief narrative description of the figure will help bring across the basic concept of the design. Key points along the figure are lettered to assist in the narrative description. Readers not interested in this amount of detail are asked to skip over the following discussion:

Point A of the figure corresponds to the inventory error singnal mentioned above. This signal is the net difference between actual observed inventory level at position II and the desired inventory level represented at point H of the figure.

Point B corresponds to the normal response action that would be undertaken by inventory managers for position II. Decision rules used in correcting errors in position II inventory may depend on the magnitude of the error, how fast the error is changing, and how long it has persisted.

Point C represents replenishment orders placed by position II inventory managers to cover the loss of stock due to fulfilling orders placed by position III managers. The smoothing lag function is used to calculate the average rate at which stocks are being depleted.

Point D represents the total or net orders placed for adjusting position II inventory toward the desired level. Note that although it was mentioned earlier that managers cannot control inventories downward by shipping grain stocks to succeeding positions, grain stocks can still be controlled downward by not replenishing stocks as fast as they are removed. Suppose, for example, the control signal at point B calls for the depletion of position II stocks at a rate of 1,000 metric tons per day. Suppose also that position III is receiving stocks from position II at an average rate of 2,000 metric tons per day. The replenishment order signal at point C of the diagram is then 2,000 metric tons per day. Net orders placed represented at point D would then be 1,000 metric tons per day, meaning that position II stocks would realize a net depletion rate of 1,000 metric tons per day.

Point E represents the constrained orders for adjusting position II inventories. We have already mentioned several limitations and constraints, such as existing stocks at position I, milling capacities, transportation capacities, etc. "Call-forward" and one-way flow limitations are also assured by the system constraint function.

Point F is a time-lag function of the order signal at point E, representing filled orders from position I into position II inventories. Note that orders in process are considered as remaining in position I inventory until delivered to position II.

Point G is a signal representing the rate at which stocks are being removed from position II inventory.

Point H is the desired level at which inventory managers at position II would like to maintain their inventories. For normal operations, managers simply desire stock levels adequate to sustain their operations for a predetermined length of time. These stock levels are planned so as to give managers the ability to respond to sudden rises in demand (orders) from succeeding position points and time to replenish their stocks.

[5] To become more specific, a series consumption, proportional-plus-derivative-plus-integral control scheme is used in the design of the price controller. The matrix equation (2) below describes the design for controlling urban rice and barley prices simultaneously.

$$\begin{pmatrix} GMKTSU_1 \\ GMKTSU_2 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} PUER_1(t) \\ PUER_2(t) \end{pmatrix} + \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \frac{d}{dt} \begin{pmatrix} PUER_1(t) \\ PUER_2(t) \end{pmatrix} + \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \int_{t_0}^{t} \begin{pmatrix} PUER_1(t) \\ PUER_2(t) \end{pmatrix} dt \qquad (2)$$

where:

GMKTSU = government grain release orders--MT/yr
PUER = error signal--observed deviation between desired price and actual prevailing market price--W/bag
A,B,C = control parameter matrices

The elements of the control parameter matrices in equation (2) describe how government release orders (should) respond to the various functions or the error signals. The diagonal elements describe release orders in response to own price errors (e.g., rice releases to control errors in urban rice prices), while the off-diagonal elements describe release orders required to compensate for cross effects among commodity prices being controlled [14].

[6] By altering these *actual* government policies and grain activities, users could investigate the "what if" type questions mentioned earlier in this chapter.

[7] The number of variables illustrated must be severely limited to preclude confusion to the reader, and to avoid the ever present hazard of too much detail for the purpose at hand.

[8] Discrepancies between actual and model generated government activities (purchases and sales) will be indicated in later summary tables. This is a subtlety of this particular test run, which has the farm and urban market choice mechanism operating. Government *demand* and *supply* throughout the run correspond to data bank values of government *purchases* and *sales*, respectively. Therefore, model generated government activities will be somewhat different than actual. Other tests of the model indicate that what has been said about the inconsistency of official government data is true; discrepancies in government activities from actual in this run make some differences in the final results, but the inconsistencies are still evident in runs which produce *exact* values of government purchases and sales.

[9] The food grain system in Korea in early 1974 was in the state of much flux. Price tracking has proven to be very difficult through this period, and therefore was not started until early May 1974 in this particular run.

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CHAPTER 17

FOOD GRAIN PRICING: ANALYSIS FOR PERIODIC PRICING DECISIONS BY GOVERNMENT

Alan R. Thodey

Governments have long been involved in influencing the price level of food grains. This involvement has increased markedly in recent years, especially in the developing countries. It ranges from food grain import and export policies to achieve desired price levels and other objectives to direct market intervention in support of those objectives. At one extreme, this direct intervention takes the form of complete government control and operation of the marketing system--from producer to final consumer. At the other extreme are relatively small-scale buffer stock and price stabilization programs aimed at normalizing the flow of grain through the marketing system by buying and storing in periods of relatively low prices and selling when prices approach unacceptably high levels. Subsidies aimed at lowering final consumer prices frequently form an integral part of these programs.

In deciding "target" price levels, governments generally attempt to achieve multiple objectives, with each objective being weighted subjectively. One of the commonly sought objectives is to increase farm output through price incentives. In some countries such as Korea, this is also accompanied by a desire to raise farm income levels relative to nonfarm incomes. At the same time, there is a desire for prices to be sufficiently low that wage earners are able to achieve a reasonable level of living, including an adequate diet. Such objectives are often contradictory and require compromise in implementation. These compromises, in turn, are conditioned by such factors as fiscal, monetary and foreign exchange limitations, as well as by government administrative capacity. Deciding how well various alternative prices satisfy the sought objectives and related constraints requires careful and detailed analysis, particularly where several major food grains are consumed.

This chapter presents one approach to the analysis of the consequences quances of alternative price levels as a basis for setting government price targets on a periodic basis, such as several times per year. The analysis employs a relatively simple, one-period projection model specifically designed to indicate the consequences of alternative prices on selected policy variables. As such, it is a problem-solving model. The actual selection of the set of prices that "best" meets the objectives of the government must ultimately be the responsibility of the policy makers, although such an analysis can produce recommendations as a basis for such a decision.

The model described was first developed and utilized in the Republic of Korea in mid-1974 to analyze alternative selling prices for government-owned rice stocks and imported wheat so as to prevent the existing government rice stock from being exhausted prior to the next rice harvest four months away.[1]. As such, it formed one of several analyses used by the Food Bureau, Ministry of Agriculture and Fisheries, in making its selling price recommendations to the government. Subsequently, it has been used to analyze the consequences of alternative producer prices for rice and barley to be purchased by the government in the months following harvest as part of the government grain management program [2, 3, 4]. The model is described in detail elsewhere [5].

Food Grain Pricing in Korea

After two decades of decreasing involvement, the Korean government began increasing its role in the grain marketing system at the beginning of the Third Five-Year Economic Development Plan in 1972. It is now a major handler of grain--equivalent to 38 and 52 per cent of rice and barley nonfarm consumption, respectively, in rice year 1975--and the primary determinant of grain prices. At the producer level, the government is the major buyer of grain in the months following harvest; the price is announced just before the government begins to buy and sets the basis for all producer-level prices during the purchasing period. Following this period, producer prices are jointly set by the private marketing system and the National Agricultural Cooperative Federation, although these prices are influenced by government release prices. As the government buys rice at one uniform price and does not offer a premium for the more preferred traditional varieties, it tends to buy mostly the newly introduced, but less-preferred, "tongil" rice. This then leaves the private and cooperative marketing system to set the premium for the preferred varieties.

Since June, 1974, the government has marketed all of its rice and much of its barley as mixed grain (70 per cent rice and 30 per cent pressed barley), with most of it being sold directly to consumers in government-controlled outlets. In addition some grain (mixed grain and barley) is released into the wholesale markets when rice and barley prices are tending towards unacceptably high levels. These releases occur at prices set periodically (now twice per year, previously once per year) by the government, and they have some influence on wholesale price levels. Such releases result in a relatively stable relationship between government release prices and private market prices. All rice and barley imports are handled by the government and are sold in the same way as domestically produced supplies.

Wheat is imported by a flour millers' association, with the government subsidizing the cost difference between the millers' cost and the controlled factory selling price. Hence, all three major food grains--rice, barley, and wheat--are included in the government's grain management operations. Beginning with rice year (RY) 1974, the cost of this program has risen dramatically, with the total deficit amounting to over $1 billion by 31 October 1975, including over $500 million incurred during RY 1975.

The Korean Government's Food Grain Pricing Decision

The Government of Korea plays a dominant role in determining producer and consumer food grain prices in support of various objectives. The major objectives are (not in order of importance) (1) self-sufficiency in rice and barley--increased production and decreased consumption, (2) improved real farm incomes (in approximate parity with nonfarm incomes), (3) reasonable food grain prices for wage earners (consistent with rising real incomes and major industrialization and export promotion programs), (4) control of inflation in food prices, and (5) minimization of foreign exchange expenditure.

In weighing various alternative purchase and release prices, the government considers the impact of these prices on the above objectives, as well as on various other aspects of the agricultural sector and the total economy. Some of the factors considered are,

1. Supply factors

   -- Effect on the level of real farm income
   -- Ratio between prices received and paid by farmers
   -- Effect on next year's supply of grain

2. Demand factors

   -- Effect on the level of real nonfarm income
   -- Contribution to inflation as indicated by the price indices of food grains and all consumer goods
   -- Effect on the level of per capita farm and nonfarm grain consumption

3. Supply-demand balance factors

   -- Effect on the level of self-sufficiency as indicated by potential grain surpluses (grain reserves) and deficits (imports)
   -- Effect on the level of foreign exchange requirements
   -- Effect on the change in the deficit in the government's grain management (special) account used to subsidize the marketing of grain

The actual selection of the prices considered to best achieve the objectives sought is a political decision. This is reinforced by the fact that weights must be placed on each objective so that the objectives can be traded off against one another. This generally results in the analyst considering various alternatives, obtaining the consequences of each alternative, and then ranking them in terms of how well they satisfy the objectives sought. These results then provide an input into the decision process selecting the final set of prices.

Description of Analytical Model

Given the above objectives and the existing availability of relevant data in Korea, it was possible to construct a relatively small, one-period model to evaluate the impact of alternative government purchase and release prices on the above factors. This model, known as the annual grain price policy analyzer (AGPPA), makes its projections by applying various change parameters to a set of initial conditions and then accounting for the consequences of the resulting changes. The central component of the model is a system of demand equations that project the per capita demand for the three most important grains--rice, barley, and wheat flour--separately for the farm and nonfarm populations, given the set of prespecified government purchase and release prices.[1] These projections are based on the per capita demand for each grain in a base period adjusted for the effect of changes in the real price of each grain (direct price effect), the real price of the other two grains (substitution effect), and the level of real income (income effect). The matrices of price elasticities used are critical in determining the reasonableness, as well as the stability, of the resulting projections: after trying several alternative methods to estimate cross-price elasticities of demand, a method using a set of substitution proportions was finally used.[2]

AGPPA contains three main operating steps. First, values for the exogenously determined (prespecified) variables and parameters are introduced for the farm and nonfarm sectors, as appropriate. These are grouped as follows:

1. Estimated per capita grain consumption in the base period
2. Projected price and income elasticities of demand
3. Projected population
4. Estimated producer, consumer, and government prices in the base period
5. Projected prices (of imports and domestic wheat) and price relationships (of government to market prices)
6. Projected nongrain price index and consumer price index weights
7. Estimated base period and projected income
8. Projected industrial grain consumption
9. Projected area, yield, and cost of production
10. Projected harvesting, storage/marketing, and import losses and processing ratios
11. Projected bag weights
12. Projected government grain handling and management costs

Second, the values of the prespecified policy variables are indicated. These are as follows:

1. Proposed government purchase (quantity) targets of rice, common barley, and naked barley
2. Proposed government purchase price of rice, common barley, and naked barley
3. Proposed government release price of rice (equivalent price in mixed grain), barley, and wheat flour[2]

And finally, AGPPA converts some of the prespecified data and projects selected variables on the basis of prespecified relationships. This includes,

1. Converted proposed government purchase targets to metric tons
2. Converted proposed percentage changes in government purchase and release prices to a price per bag at the producer. wholesale, and consumer levels

3. Projected production and consumable domestic output

4. Projected average producer and consumer prices (based on (2) above)

5. Projected gross and net farm income and the proportional change in real per capita farm income over a reference period

6. Projected per capita demand and total human and industrial consumption requirements

7. Projected quantity and foreign exchange costs of imports required to fill the gap between the projected requirements and the consumable domestic supply of each grain (and ratio of self-sufficiency)

8. Projected government grain management costs (change in the deficit in the Grain Management Special Account)

9. Projected level of the consumer price index for grains and for all items

The model is structured to project one period ahead from a base period, which is generally a best estimate of the current situation. The projection period can be of any time length, such as one season or one year, but it must be the same length as the base period. For the grain and consumer price indices, a reference period that may precede the base period is permitted; however, the reference and base periods may coincide. On the supply side, four commodities are included--rice, common barley, naked barley, and wheat. On the demand side, three commodities are included--rice, barley, and wheat flour (or in some cases, wheat).

Example of Model Application

Policy Assumptions

Seven alternative sets of purchase and release prices were analyzed for the rice purchase price decision in rice year (RY) 1976 (1 November 1975 to 31 October 1976). As barley purchase prices had been raised the previous July and rice and barley release prices and wheat factory prices the previous April, the average increase (weighted equally by month) of barley and wheat flour prices in the previous year was assumed to represent the average increase during RY 1976. The alternative increases considered in rice prices were as follows:

Alternative	Rice Purchase Price	Rice Release Price*	Other Prices	
	(percentage of change over RY 1975)			
1	20	20	Purchase Prices	
2	20	30	Common barley	22.1
3	25	20	Naked barley	22.1
4	25	25	Release Prices	
5	25	30	Barley	20.6
6	30	20	Wheat flour price	20.0
7	30	30		

*Based on the equivalent price of rice sold as mixed grain, assuming barley prices as given.

The alternative price changes selected were judged to represent the most likely range of rice prices that would be considered by the government. This was based on the following factors:

1. The price increases announced earlier in the year for grains, particularly barley
2. A rise in the private market price over the previous year of medium-quality rice of 29.6 per cent by July, 1975

3. Increases in the index of prices paid by farmers throughout Korea of 18.4 per cent for farm supplies, wages, and charges; and 22.9 per cent for all consumption items during the year to June, 1975

4. Increases in the consumer price index in all cities of 27.7 per cent for all items, 51.4 per cent for cereals, and 21.4 per cent for all noncereal items during the year to June, 1975

5. A negligible increase of .8 per cent in the index of all prices received by farmers relative to that of prices paid by farmers in the year ending June, 1975 (the previous year, this parity ratio fell by 3.2 per cent)

6. Farm productivity was projected to be possibly 5 per cent higher, due to a projected rice production increase of up to 3.6 per cent and a decline in the number of farm families of 1.8 per cent

7. Even through Korea was possibly self-sufficient in rice in RY 1975, it has a strong desire to build buffer stocks over the next few years by encouraging rice production (partly through favorable prices) and discouraging rice consumption (partly through unfavorable relative prices)

8. A desire on the part of the government to reduce its grain management deficits, partly by increasing release prices relative to purchase prices

The government purchase targets assumed in the analysis were as follows:

Cost	Purchase Target			Harvested Production*	Target as Percentage of Production
	Basis		Quantity		
			(1,000 Metric Tons)		
Rice	Target	RY 1976	1,008	4,387	23
Barley					
Common	Actual	1975	182	823	22
Naked	Actual	1975	338	1,161	29
Wheat	Actual	1975	---	127	----

*Crop cutting survey yield adjusted for harvesting losses and seed.

The target for rice was already determined by the government on the basis of its past experience and financial, administrative, and logistical capacity. The purchase targets for barley had already been achieved several months earlier.

Results of Analysis

Farm income (net return to farm resources) per household from rice is projected to rise by 27 to 40 per cent at most over RY 1975 as the average producer price is raised by 20 to 30 per cent, respectively (Table 1). Three factors are working together to raise income per household faster than the average increase in prices: (1) average production costs are assumed to have risen by 18.4 per cent over RY 1975, (2) average yield is projected to increase by 3.6 per cent, and (3) the number of farms is projected to decline by 1.8 per cent. The average increase in farm income from all grains is even more favorable and ranges from 31 to 43 per cent. The actual increase in farm income is likely to be less than this, because the actual outcome of the above three factors is most likely to be less favorable than projected.[4] Also, the "real" increase in income will be much less because of the effect of price inflation. For example, the index of prices paid by farmers for all consumption items rose by 22.9 per cent during the year to June, 1975.

Under the price increases assumed for farm and nonfarm households--20 to 30 per cent,[5] Table 2 indicates that per capita rice and wheat flour consumption is projected to increase in RY 1976 and barley consumption to decrease. The only exception to this is farm households responding to a 30 per cent increase in producer rice prices, where per

Table 1. Projected Consequences of Alternative Purchase and Release Prices for Rice in Rice Year 1976

Alternative	Farm Income Per Household[1]		Total Consumption Requirement						Self-Sufficiency Index[2]		Foreign Exchange Costs[3] (millions of U.S. dollars)	Change in GMSA Deficit[4]	
			Rice			Total Grains							
	Rice	Total	Farm	Non-Farm	Total	Farm	Non-Farm	Total	Rice	Barley		Rice	Total Grains[5]
	(percentage of change over RY 1975)												
1	27	31	-.7	5.6	3.4	-1.7	4.3	2.2	101	101	369	44	108
2	27	31	-.7	4.1	2.4	-1.7	3.9	1.9	102	101	372	25	89
3	34	37	-1.4	5.6	3.1	-1.9	4.3	2.1	101	101	370	53	127
4	34	37	-1.4	4.8	2.6	-1.9	4.1	2.0	102	101	372	44	107
5	37	37	-1.4	4.1	2.2	-1.9	3.9	1.9	102	101	373	34	98
6	40	43	-2.1	5.6	2.9	-2.0	4.3	2.0	101	102	371	63	127
7	40	43	-2.1	4.1	1.9	-2.0	3.9	1.8	102	101	374	44	108

[1] Return to land, capital, labor, and management per farm household. Increase in return from common barley, naked barley, and wheat projected at 69, 53, and 35 per cent, respectively, under all alternatives.

[2] Self-sufficiency index = $\frac{\text{Consumable domestic production}}{\text{Total consumption requirements}}$ X 100. Wheat and total grains projected to average 4 and 78 per cent, respectively, under all alternatives.

[3] Wheat only (rice and barley surpluses assumed to be stockpiled rather than exported).

[4] The change in the Grain Management Special Account deficit indicates the cost to the government of its grain operations. Deficit for barley and wheat projected at 24 and 28 billion won, respectively, under all alternatives ($1 U.S. = 485 won).

[5] Includes 11 billion won for interest on the accumulated GMSA debt as of October 31, 1975.

Source: [4], Tables 2-7.

Table 2. Projected Per Capita Grain Consumption under Alternative Rice Prices in Rice Year 1976

Increase in Rice Purchase Price (percentage over 1975)	Per Capita Farm Consumption				Increase in Rice Release Price (percentage over 1975)	Per Capita Nonfarm Consumption			
	Rice	Barley	Wheat Flour	Total		Rice	Barley	Wheat Flour	Total
	(kg/capita)					(kg/capita)			
20	108.5	63.7	37.7	209.9	20	123.8	44.7	42.6	211.2
25	107.8	63.6	38.0	209.4	25	123.0	44.8	42.9	210.7
30	107.0	63.4	38.4	208.9	30	122.1	44.9	43.2	210.2
	(percentage of change over 1975)					(percentage of change over 1975)			
20	1.0	-2.0	2.1	.3	20	2.0	-2.8	2.5	1.1
25	.4	-2.1	2.9	.0	25	1.4	-2.6	3.2	.8
30	-.4	-2.4	4.0	-.2	30	.6	-2.4	3.9	.6

capita rice consumption declines slightly (0.4 per cent). These changes are offsetting and result in per capita total grain consumption being relatively stable--the change over RY 1975 for farm households is projected to be only from -0.2 to 0.3 per cent and from 0.6 to 1.1 per cent for nonfarm households. The changes in per capita grain consumption result more from the effect of increased real income (e.g., assumed to be 8 per cent for nonfarm households) than from the effect of increased real grain prices. In fact, a 20 per cent increase in purchase and release prices has no effect on consumption, since a 20 per cent increase in nongrain prices (the deflator to obtain real grain prices) is assumed. Hence, the effect of 4.2 and 8.3 per cent real increases in rice prices are indicated by grain price increases of 25 and 30 per cent.

The total consumption requirement can be estimated by applying a population projection to the per capita consumption estimates (Table 2). While total farm requirements are projected to decline, these are more than offset by projected increases in nonfarm consumption (Table 1). These changes, however, are largely explained by a 1.8 per cent decrease in the farm population and by 3.5 and 1.5 per cent increases in the nonfarm and total populations, respectively.

Comparing the consumable output (production adjusted for harvest and market losses and self-produced grain fed on farms) with the human, industrial, and purchased feed consumption requirement, Table 1 indicates that Korea is expected to be self-sufficient in rice and barley in RY 1976 (Table 1). A similar achievement was expected in RY 1975 when the build-up in stocks was expected to exceed imports; in fact, it now appears that the projections were somewhat optimistic as a slight short-fall occurred. Nevertheless, even near self-sufficiency is a noticeable achievement, since Korea had imported a significant proportion of its rice and barley supplies in previous years. If self-sufficiency is achieved in RY 1976, then only wheat imports will be necessary. This will result in a drop in foreign exchange costs over RY 1975 of about 40 per cent under all alternatives.

The cost of government grain management operations (GMSA deficit in Table 1) in RY 1976 is projected to range from 89 to 127 billion won ($184-262 million U.S.), including interest of 11 billion won on the accrued debt. The percentage of change from RY 1975 rages from a decline of 20 per cent (alternative 2--a 20 per cent increase in purchase prices and a 30 per cent increase in release prices) to an increase of 15 per cent (alternative 6--reversing the percentage of increases of alternative 2).

The impact of the three alternative rice release prices--20, 25, and 30 per cent above the average for RY 1975--on the grains component of the consumer price index (CPI) is 20, 25, and 29 per cent, respectively. Assuming an average increase of 20 per cent in the nongrain components of the CPI, then the overall increase in the CPI is 20, 21, and 22 per cent, respectively.

Policy Suggestions

The criteria for deciding government grain prices in RY 1976 should be the effect of alternative prices on (1) the level of price inflation, (2) the level of "real" and money income per farm household from grains;

(3) the production of grain in RY 1977; (4) the cost to the government of its grain management operations; (4) rice and barley self-sufficiency; (5) foreign exchange expenditure for grain; and (6) the adequacy of grain consumption, especially by lower-income households. The actual order of importance of these factors depends upon the weight the government attaches to each of these factors.

Probably the most important of these factors for RY 1976 is the cost to the government of the prices selected. Not only is there an overall budget limitation, but there is increasing awareness of the role the resulting deficit has been playing in the overall rate of inflation in Korea. In addition, the differential effect on the other factors appears to be less marked or of a lesser significance. For example, goals of achieving self-sufficiency in rice and barley production and in achieving parity of farm and nonfarm incomes (in terms of real living standards) are relatively close to being satisfied. Hence, it seems that food grain pricing policy should be directed towards maintaining the parity of farm incomes while trying to substantially cut the cost of government grain management operations. This suggests that the increase in rice release prices should run ahead of the increase in rice purchase prices by 5 to 10 per cent (such as in alternatives 2 or 5).

This type of analysis highlights the interdependency of (1) purchase and release prices; and (2) the supply, demand, and price situation for all food grains and the need for all of these factors to be considered in formulating a grains pricing policy in Korea. The trend in Korea towards considering more than one price at a time is encouraging and should be continued.

Summary and Conclusions

Through the use of a relatively simple problem-solving model--the Annual Grain Price Policy Analyzer--it has been possible to provide a better basis to the Government of Korea for formulating its food grain pricing policy. This model incorporates a system of demand equations to simultaneously project the per capita demand for three food grains in the farm and nonfarm sectors in the next period. The projection of other relevant policy variables is based on prespecified relationships, using these demand projections and other exogenous estimates and projections.

AGPPA was developed for a specific purpose, and its results must be interpreted within that context. Its main purpose is to provide projections on variables considered relevant to the periodic setting of government purchase and release prices under alternative sets of prices. One result of its use has been to encourage increased consideration of the consequences of alternative sets of purchase and release prices for several grains.

Several modifications to the model are possible that would significantly improve its usefulness. First, the rice-barley mix is really a separate grain, with its own distinct demand characteristics, and so should be included separately in the model. Data are expected to become available shortly that would permit the relevant parameters and relationships to be estimated. Second, the model presently does not project the impact of the cost of government grain operations on overall price levels (assuming that it continues to add to government borrowings). Third, by restructuring the model, it seems possible to set it within a linear programming framework. This would permit purchase and release prices to be derived that would optimize the most important policy objective; the remaining policy objectives would be incorporated as constraints.[6] Fourth, by incorporating a set of supply response fuctions in the model, it could provide projections of the impact of alternative prices on food grain supplies in the following year. And finally, alternative import and buffer stock policies could be incorporated into the model. These could be time- or quantity-dependent, if desired.

FOOTNOTES

[1] As finally used in Korea, AGPPA requires that government purchase and release prices be prespecified. Then it solves for projected per capita demand. The initial model was more general, since it permitted any combination of prices and per capita demands to be prespecified and then solved for the remaining variables (three for each population). See [5], Appendix B.

[2] The elasticities estimated from regression analysis proved to be sufficiently inconsistent that they could not be used directly. This appears to be the result of various nonprice and nonincome factors not included in the statistical analysis of time-series data. Instead, the income elasticities used were obtained from the analysis of the most recent cross-section data; own price elasticities, from the analysis of time-series data on the basis of reasonableness and of consistency with other estimates; and cross-price elasticities, from judgments by food grain specialists about how the other two grains substitute for each grain as its own prices change. An important factor considered in making these judgments was the historical tendency for total grain consumption in Korea to remain relatively stable, despite substantial shifts in the consumption of individual grains. See [5], Appendix B.

[3] The average factory selling price of wheat flour is controlled by the government, rather than by the flow of flour stocks directly.

[4] This occurred, in fact, with the yield of rice, where disease and weather factors resulted in a lower-than-expected yield.

[5] Average producer prices for farm households and average consumer prices for nonfarm households.

[6] The basis for such a model, identified as the "Optimum Prices Submodel--AGPPA 2," is described in [5], Appendix C.

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PART FOUR

FUTURE DIRECTIONS
FOR THE
GENERAL SYSTEM SIMULATION APPROACH

CHAPTER 18

FUTURE DIRECTIONS

George E. Rossmiller
Glenn L. Johnson
Tom W. Carroll
Michael H. Abkin

Introduction

In earlier chapters a general system simulation approach to agricultural sector development planning and policy investigation was discussed. Development, institutionalization, and utilization of the approach were discussed, using Korea as the case example. In this chapter it is appropriate to summarize the lessons learned from this experience and to indicate the various future directions which further development and application of the approach should take to be widely useful to agricultural and rural sector planners and decision-makers in both developing- and developed-country contexts. The discussion on further directions follows two main paths. The first deals with the transferability of the general system simulation approach as now developed for national agricultural development planning and policy investigation. The second deals with the futher development potential of the general system simulation approach for even greater usefulness in agricultural development planning and policy investigation and greater usefulness in the broader arena of rural sector development. Discussion is concluded by specifying potential users of the approach.

In addressing these important issues of future directions, it is necessary to keep in the mind the major tenets of the general system simulation approach. The approach is a broad and flexible means of enhancing an investigative capacity for decision-making. As focused in the chapters of this bock, it pertains to public sector decision-making at the national level for agricultural sector development. The core ingredients of the approach consist of sets of logical frameworks, or models, both formal and informal, designed to provide information useful in solving sets of interrelated problems within a given subject-matter context. Developed in a building block or modular format, the components and models are adaptable and flexible enough that through innovative combination and use, they can provide information required for the solution of specific problems. The generality of the approach refers to its eclecticism in its philosophic orientation, in its use of modeling techniques, in the sources and kinds of data and information employed, and in the dimensions of the subject matter addressed, most importantly including time and space.

It makes use of both normative and positive information in (1) determining appropriate decision rules to use in prescribing actions for problem solution (2) prescribing problem solutions and (3) projecting the consequences of alterantive courses of action. The approach takes a systematic view in modeling the domain of a problem or the domain of the common parts of problems in a set. It provides for evolutionary adaptation and extension of the models to adequately represent the changing reality they are designed to reflect.

The approach requires that the models be integrated with the administrators, decision-makers, and affected people as part of the problem-solving, decision-making process. It also requires linking and integration with supporting services, such as research institutions, data and information acquisition systems, computer installations, and institutional sources of trained personnel.

Transferability of the General System Simulation Approach as Currently Developed

Simply posed, the question of transferability is whether the general system simulation approach, which has proven effective and useful in two environments and applications, Nigeria and Korea, can successfully be transferred and used in another.

Transference to different geographic locations or different countries, if you will, means that the approach can be institutionalized and utilized in different problems or problem set contexts in environments different with respect to physical conditions; resource endowments; human capacities; and socio-economic, political, and institutional conditions. Countries exist in different stages of agricultural and general economic development. Political philosophies and approaches are different functions in diverse societies among countries. The physical constraints of climate, topography, soils, water conditions, and bio-mass development vary widely among countries. Also different are the resource endowments with respect to land and its improvements, the level of technology, man-land ratios, population distributions, labor capacities and skills, cropping and livestock patterns, level of agricultural sector modernization, state of industrialization in the nonagricultural sectors, capital-generation capacity, and foriegn trade potentials.

Finally, great disparities exist among countries in their national capacities for problem-solving decision-making with respect to agricultural sector development. The question of the level of national decision-making capacity required for successful institutionalization and utilization of the general system simulation approach, while related to the other questions, is sufficiently different to require treatment in a separate section below. Let us first turn our attention to the impact of the differences among countries indicated in the paragraph above on transferability of the approach.

Model Structure Transferability

The core of the approach is conceptualization of models necessary to adequately (for the solution of the problems at hand) reflect the processes and linkages within the system under consideration. As we have indicated earlier, the formal part of this modeling process has three parts. The first is the logical framework, or model strucutre, which, through the use of various methodologies and techniques, incorporates theories of relevant disciplines to depict the physical, biological, and socio-economic conditions and processes of the real-world system in sufficient detail to be useful in decision-making. This model structure can be displayed in a variety of ways, including system block diagrams, mathematical equations, computer programs, or verbal descriptions. The second part of a model is the parameter estimates required to indicate the linkages within the model structure and the rates of change in the key variables over time, through space, and in other dimensions. The final part of a model is the initial condition data and information required to describe the state or condition of the system at a given and known or historical point in time and space.

By definition initial condition data and information are time- and space-specific and, therefore, not amenable to transfer. Parameter estimates are probably somewhat less time and space specific; but, nevertheless, since they depend upon unique combinations of physical, biological, and socio-economic conditions, few, if any, are likely to be transferable. In rare cases, parameter estimates from one time and location may be used as best estimates of parameter estimates in another, if no better data are available. An example of such use is found in Manetsch, *et al.* [7], where, because of an absence of population data in Nigeria, the population component of the Nigerian model was parameterized using age-sex population distributions, birth rates, and death rates from Dahomey.

The part of a model with the greatest potential for transferability is the model structure, especially its individual components. A computerized model is generally composed of a series of routines and components assembled in a meaningful way to reflect a real-world process. These routines and components can be generalized in a manner allowing for their use in a variety of applications. For example, in an aggregate agricultural production model, a distributed delay routine can be used to reflect the gestation period for fruit orchards or rubber plantations, as well as for various types of livestock. The same delay model structure can be used to reflect the arrival of grain shipments at a domestic port from foreign sources. Similarly, at the component level, a demographic component, which steps a population through a series of age cohorts, can be used to reflect human, tree, livestock, or machinery populations. The structure of a demand component, which accepts population and income as demand shifters and includes own- and cross-price elasticities to reflect price quantity linkages will be the same in a variety of countries, although the actual parameters and initial-condition data will, of course, be different.

At the sector model level, it readily can be seen that the population dynamics; the physical, biological, and socio-economic processes in production, marketing, and consumption; and the impacts of investment, price, trade, and control policies affecting the system operate in generally similar ways, without reference to time and space. Differences in physical conditions, resource endowments, political philosophy, socio-economic structure, technological levels and rates, and a host of other variables can be reflected with marginal changes in model structure and through the time- and space-specific parameter estimates and initial condition data.

Recognizing the generalizability of routines and components comprising model structure, one can readily see that generalized versions of much of the model structure developed under the general system simulation approach can be applicable to other subject-matter areas and problem contexts, such as health, education, industrialization, transportation, the military, and space. We will, however, continue to concentrate in the present discussion on application of the approach to agricultural sector development.

Means of Transfer

Effective transfer of the general system simulation approach and its application in other geographic locations, subject-matter areas, or problem contexts can be effected in a variety of ways. They can, however, be classified into the two main categories of experience and knowledge.

Experience can be transferred directly in two ways. The first is through direct provision of technical assistance and consultancies, long or short term, by individual professionals who have developed a body of experience in building, institutionalizing, and utilizing the approach in other areas or contests. The second is by experiential transfer through various forms of training. Such training can be formal or informal and consists of classroom instruction, institutes, workshops, seminars, and/or on-the-job training.

Knowledge may be transferred through publication of books (such as this one), reports, monographs, and papers describing the approach, the administrative and anlytical processes, and specific examples of utilization. Another important means of knowledge transfer is through documentation, classification, and storage for dissemination of computerized models, components, and routines developed and used in a variety of locations and contexts. A third means of knowledge transfer is through data management systems and data banks accessible to those in a variety of locations requiring such data. For any country with an open economy, a wide array of data and information on production, consumption, and economic conditions of the world and regional economies of which such a country is a part will be important to agricultural sector decision-making.

Prerequisites for Acceptance of the Approach

In order to transfer, adapt, institutionalize, and utilize the approach in a new geographic location, subject-matter area, or problem context certain prerequisite conditions must hold. Again, we will concentrate on the transfer of the approach for agricultural sector development planning and policy analysis, while recognizing that the discussion can be generalized from the public to the private sector, as well as to other subject-matter and problem situations. The first prerequisite is a commitment on the part of national-level government decision-makers to an improved national decision-making capacity for agricultural sector development. This requires an interest in utilizing information input by investigative agencies and staff in the decision process and an adminstration capacity allowing for utilization of such input. Further, there must be a willingness on the part of decision-makers to interact with their investigative bodies throughout the decision process.

A minimal investigating capacity must already be in place. This must include a cadre of trained professional investigators, who, with further training and experience, can further develop and utilize the models and techniques, interact with decision-makers in appropriate ways, and analyze and synthesize their data and information in ways useful in the decision-making process. In addition, some form of data base and a data and information acquisition system must be available. This would include at a minimum a capacity to generate a set of national agriculture accounts for farm numbers, inputs, production prices, marketings, incomes, and population. A willingness and ability to reorganize and commit additional resources to improvement of the data and information system are necessary to sustain the effort. Another necessity is a computer hardware and software system available to the investigative units, staffed by competent personne[illegible]ving the ability to use, maintain, and administer the computer service system.

These prerequisites are required in some form and at some level for any transfer of the approach to take place. In some countries and in some situations, the appropriate procedure may be to phase the transfer of the approach over a relatively long period of time. This would require beginning with relatively limited objectives, a low-level training program, and little or no direct input by foreign consultants or technical assistance personnel. In other cases a much higher level of initial activity may be indicated. Whatever level of activity is specified, however, the full range of prerequisites is necessary at commensurate levels.

As part of a country's investigative capacity, the university system must also be involved for successful transfer of the approach. The most important contribution by the universities is teaching and training--the basis for sustained activity in further development and utilization of the approach. Disciplinary skills must be available, maintained, and taught to succeeding generations of students, some of whom will become part of the country's investigative capacity in university faculties or as staff in government investigative or administrative agencies. A further contribution of the university system, in conjunction with maintaining and teaching disciplinary skills is the disciplinary research required for expanding the theoretical and methodological knowledge base. A third contribution by the university system is the integration of disciplinary knowledge and its application to increasing the stock of information and knowledge about various subject-matter areas such as agriculture structure, land tenure, water resource development, mechanization, rural employment or marketing. Finally, somewhat less frequently, the university system can provide input to the direct solution of specific problems.

The Role and Limitations of External Assistance Agencies

The major role external aid and technical assistant agencies can play in transferring knowledge and experience gained in development and application of the approach to other developing countries is through funding projects for that purpose. The aid granting agencies--such as the U.S. Agency for International Development, the Food and Agriculture Organization of the United Nations, the United Nations Development Program--and the major foundations involved in international development activities, such as Ford and Rockefeller, all include as part of their objectives assistance to developing countries in building greater investigative capacity for agricultural sector development decision making. Such agencies and institutions can contribute to the satisfaction of this objective through support of a variety of interrelated activities.

Most of these organizations have subunits charged with the responsibility of supporting and/or collecting relevant disciplinary and subject matter-research which can be useful in a variety of programmatic contexts. All of these organizations have subunits which are geographically oriented and which include field offices in developing countries. These subunits can greatly benefit from support of user oriented subject-matter research and program solving activity focused toward and in conjunction with specific host countries. In connection with these research and operational activities some of the aid granting agencies support training programs for human capacity development, conferences for wide dissemination of the results of research and operational activities, and institutional development projects to contribute to human capacity development and institutional, organizational, and administrative structures allowing for fuller and more efficient utilization of such human capacities. Systematic and comprehensive development and institutionalization of investigative capacity for agriculture sector decision making, whether through the general system simulation approach or through other similar means, requires coordination of existing activities of assistance agencies. New and innovative ways of carrying out existing activities and even additions to present types of programs and projects can be greatly beneficial. Some of the new and expanded kinds of activities which assistance agencies might attempt are indicated below. First, however, some comments on the limitations of external assistance are in order.

Unfortunately, aid-granting agencies generally have little or no professional capacity within the institutions to provide the technical assistance, consulting, and training required to effect transfer. Even though these agencies have the critical administrative and programmatic links with the developing countries, they must, in the final analysis, rely upon professionals from universities in developed countries, government agencies, and consulting firms to carry out the work prescribed in specific project statements. Project development, administration, and execution within this interntional assistance system has often been extremely costly, subject to the whims of assistance agency administration or even more remote governing bodies, and much less relevant and successful than might have been the case. With relatively rapid rotation of personnel, assistance agencies tend to have little memory and short planning horizons for any given program thrust. The result is often development of project substance and design, without the benefit of past experience and without consistent direction and support throughout the course of the program. Finally, programmatic support for many of the international assistance agencies is based on an annual budget cycle, with planning limitations usually of not more than three years. This introduces another potentially disruptive influence into the already fragile structure designed to carry out assistance projects.

Role of Developed Country Universities in Technical Assistance

In addition to serving in the capacities indicated above in thier domestic setting, a role of developed-country universities is to assist universities and government agencies in developing countries in many of the aspects of building and institutionalizing an indigenous investigative capacity. This necessarily involves technical assistance and consulting with the university system and the government on organization, administration, development, institutionalization, and utilization of various components of such a capacity, as well as the training of developing-country personnel in the developed country's universities in graduate and/or nondegree programs. Funding for such activities, for the most part, must come from sources other than the universities of the developed country themselves, such as host-country governments, national bilateral aid institutions, and international technical assistance agencies.

University faculties are the major source of personnel for staffing technical assistance projects funded by the assistance agencies. Such involvement can be extremely useful to individual faculty and to universities as a basis for relevant disciplinary and subject matter research and a source of practical problem solving experience. International projects provide a rare opportunity for universities and their faculties to produce multidisciplinary output focused around real world problems. This experience and research opportunity improves the productivity of university faculty and the quality of classroom teaching.

Such involvement is not without cost. One obvious cost is the opportunity cost of faculty time. Another is the overhead cost both in terms of time and money of negotiating and administering grants and contracts. Public and private university governing bodies and state legislatures, at least until the present, have been unwilling to commit endowment funds or state appropriations to international activities of university faculty on the contention that such funds ought to be used for direct domestic or state advantage. For the most part, university administrators have been unwilling to take the risk of staffing positions expressly for international activities, due to the vagaries of project funding from the international assistance agencies.

Project staffing has often been done with the young, untenured, and inexperienced; the retiring, interested in a relaxed decompression assignment; or the mid-career person looking for a break, a new experience, and an enjoyable place to travel, but without commitment or experience in international project activities. Since private consulting firms often staff with university personnel from the last two categories, they do not fare any better than the universities. Without a strong commitment to international activities by university administrators and state legislators, the reward system overtly or inadvertently penalizes involvement in international activities and thus makes international development careers by individual faculty members at best a high-risk venture.

Recently the U.S. Agency for International Development and U.S. universities have been searching jointly for new mechanisms to ease the burdens to both AID and the institutions in carrying out collaborative work. The basis for the new form of collaboration includes the cost sharing principle reflecting mutual benefit on the part of the universities and a recognition on the part of AID that university involvement in international agricultural development programs constitutes a unique relationship between AID, the host country and the university requiring flexible, long-term arrangements. It is too early to determine whether the new mechanisms will be operationally effective but the fact that the attempt is being made is encouraging.

Role of Host Country Institutions Related to Technical Assistance

Factors within host-country institutions also contribute to the difficulty of carrying out long-term, well-designed projects. A combination of rapid turnover of host-country government and university officials; often an atmosphere of suspicion and distrust of the motivations of assistance agency personnel; inadequate resoruces, administrative capacity institutional structures; a limited cadre of professional personnel; and a lack of clear understanding of program objectives contribute to less-than-satisfactory project outcomes. A clear assessment of the resources available and capacities of personnel in host countries to jointly carry out external assistance programs is necessary. It is well for all parties concerned to recognize that not all developing countries are ready and able to make the commitments necessary to successfully carry out programs to build investigative capacity for agricultural sector development decision making.

Finally, conflicts of interest and perspective often arise between the host-country officials interested in the project for problem-solving reasons; the funding agency personnel, who tend to focus on a subject-matter orientation to build a stock of knowledge which may be useful in a variety of countries in which they have activites; and the university personnel who staff the project with a disciplinary orientation. Small wonder that most projects turn out less than perfect!

Despite all this, some progress is being made. One hesitates to list examples when, due to imperfect knowledge and inadequate space for full discussion, unwise inclusion or inadvertent omission will not do justice to this important field of activity. Nevertheless, we can suggest that in the Asia and Pacific region, in addition to the Korea-Michigan State University activity, two others will bear watching for their sustained impact on the future planning and policy analysis endeavors of the country involved. One is in Thailand, where Iowa State University has been involved for the past five years in helping the Thai Ministry of Agriculture develop their planning and policy analysis capability. The other is in the Philippines, where a team from the U.S. Department of Agriculture has been assisting the Philippines Department of Agriculture along the same lines.

The Thailand model consists of 19 regional production submodels, a national crop model and a macroeconomic model. The regional and national crop models are linear programming type models while the macroeconomic model is a combination input/output and econometric model. The Philippine model relies exclusively on linear programming techniques. The Thailand and Philippine models are much narrower in their use of modeling techniques and thus are more limited in the types of data used than the Korean model. The Thailand model has regional detail unavailable from either the Philippine or Korean model.

In all three of these projects the prerequisites for project implementation were met by the host countries. The projects were staffed with competent and dedicated personnel, and a mutual trust and good working relationship was established early on between project staff and host country personnel. In addition, all three projects had the advantage of project extensions, allowing the expatriate team to continue a presence in the host country over a long enough period of time that indigenous personnel could gain both training and experience during project tenure. Full, objective assessment of the value of these projects in building a high quality modern investigative capacity of sustained usefulness to agricultural sector development division makers will not be possible yet for several years. Present indications however are promising.

Basis for Approach Transfer

The Agricultural Sector Analysis and Simulation Projects team at Michigan State University included in their project design two activities for development on an experimental basis to provide a basis for transferring the general system simulation approach in agricultural sector development to other interested developing countries. These are the Development Analysis Study Program and the Computer Library for Agricultural Systems Simulation.

Development Analysis Study Program

This training program has two components--the first, a basic study program of approximately one year's duration to strengthen the investigative side of the national decision-making capacity and an administrator and decision-maker orientation study program designed as one- to two-week workshops to strengthen the administrative side of the national capacity.

The basic study program is designed to provide the student with the skills required for limited model development, model maintenance, and use. It consists of regularly scheduled university course work in systems science, agricultural economics, computer science, and economics supplemented by course work in other agricultural or social sciences. In addition to the regular course work, special intensive application-focused seminars are provided. Each student chooses a special project in which he designs and implements a model based on a policy problem from his own country. In carrying out the special project, the student has available to him tutorial help in computer programming and sufficient computer time to carry through his model development and analytical work. Experience with this program in Korea has indicated that while it does not substitute for graduate degree programs it can be an extremely important element in supplementing the more highly trained cadre of investigative personnel. This training can be taken as part of a Masters Program, a field in a Ph.D. program or as a nondegree course of instruction. Students entering for a one-year course of instruction should already have a Master's degree in their special field and a command of mathematics through calculus. Training at this level is inexpensive and quick, relative to degree programs, and if done early in conjunction with projects involving expatriate help, it can provide indigenous personnel with the skills and perceptions required to work most effectively with the expatriate teams while other indigenous personnel are engaged in the longer-term, higher-level training.

The orientation study program consists of one- to two-week workshops designed to provide administrators and decision-makers with a basic understanding of the system approach, planning, and management; the capabilities and limitations of quantitative methods, models, and model concepts; the role of investigative input to the decision process; and the interactive role they must play to make the most effective use of such investigative input. The orientation study program was tested in Korea with approximately 30 administrators and decision-makers in attendance. The program was well received and appeared to have been useful in subsequent project activity. A major lesson learned, however, was that future workshops should be held far enough away from participants' offices to assure full-time attendance. In addition, for middle- and top-level officials, one week is probably the upper limit of time they can afford for such an activity and then only if scheduled well in advance.

Computer Library for Agricultural Systems Simulation

This library is based on the concept pointed out earlier that while parameter estimates and initial condition data are time and space specific, much of the model structure depicting physical, biological, and socio-economic behavior processes is not. Thus, much of the model structure required for subject-matter and problem-oriented modeling of an agricultural sector for agricultural sector planning and policy analysis has the property of generalizability. Model structure reflecting socio-economic processes are general in two dimensions. First, a model may be of a generalized process. For example, a model of a demographic process may be used for human, tree, livestock, or capital equipment populations, while a processing model may be suitable for the processing of cocoa, oil palm products, rubber, or tobacco. Second, a model may be generalized with respect to applications. A population model, a demand model, or a production model may be applicable to analyses of food production problems in Tanzania, cattle industry problems in Venezuela or Colombia, or agricultural sector problems in Nigeria or Korea. With this in mind, the software library (CLASS) concept was developed to capture past model structure development (as capital stock) to be utilized in a variety of contexts other than those for which they were originally developed.

As stated in the July, 1976, progress report [1], "The Computer Library for Agricultural Systems Simulation (CLASS) is viewed as a unit which acquires, catalogues, maintains, and distributes computer programs and associated documentation. These computer programs are of generalized simulation models and routines designed specifically for the analysis of agricultural development problems and processes. In particular, the library catalogues and indexes programs and documentation so as to facilitate their retrieval by users seeking a set of programs to be used in a specific problem analysis and distributes programs and documentation to users."

"To enhance the effectiveness of the library, its functions also include identifying and soliciting needed models, actively bringing programs and documentation up to the library's standards, and providing limited consultation in identifying and implementing appropriate library programs for a particular application. A subsidiary function of the library, in conjunction with the identification and solicitation of models, is to survey and catalogue ongoing research in agricultural systems modeling and simulation."

To carry out the functions indicated, the library must be an institutional entity capable of performing activities in three areas: (1) acquisition and development of routines, components, and models, with associated software and documentation; (2) storage and maintenance of these software elements; and (3) user-related services, such as software retrieval, consulting, and training. Acquisition of elements into the experimental software library, developed at Michigan State University, has been limited to the routines, components, and models developed by the Agricultural Sector Analysis and Simulation

Projects from their work in Nigeria and Korea, as part of the related training activity under the Development Analysis Study Program, and dissertation research in conjunction with regular graduate degree programs.

Documentation has been based upon the standards set forth in the Software Standards Manual [3], developed as part of the library activity. The Software Standards Manual sets out documentation standards which will (1) maintain a consistent programming style, (2) maintain a compatibility among computer programs, (3) ensure and facilitate adequate error checking, (4) facilitate further development, (5) enhance readability, and (6) ensure as much machine independence as possible.

Storage of the software library offerings is on computer tape, with documentation of each routine, component, or model published in the CLASS document series. User-related services have taken place primarily internally as part of the library concept testing producers and have been used primarily in doctoral research projects.[1] From these test examples, CLASS appears to be a sound and potentially valuable concept for preservation and utilization of model structure capital stock.

The concept of model structure software as capital stock is relatively new and, obviously not widely held by modelers and analysts. Most modelers tend to prefer the creativity of their own modeling, rather than to borrow and reassemble from that which has gone before. This is in part a reflection of historical training, which places a higher reward on individual creativity, partly due to inadequate documentation, which makes the models difficult to use by anyone other than those who created them, and in part due to the notion that model development is a means to a limited objective, which normally ends with the publication of a report and with no intent that the model will continue to be used as the subject-matter arena changes and as new problems arise within that subject area. It would behove all modelers and analysts to recognize that redoing that which has been done before is a shameful waste of scarce resources. New and unique contributions to software repositories should be judged worthy contributions in peer group reviews. Mechanisms allowing for ease of access and use of modeling software from such repositories could substantially enhance the capacity and capability of modelers and analysts.

While the concept of a software library has been developed to a limited utilization stage at Michigan State University, it is not clear that it should remain at that location. At a minimum, it should be institutionalized in one or more international agencies dealing with the subject matter and problems in a variety of locations and contexts for which the content of the library can be of use. Possible repositories for the library, with the appropriate institutional structure to maintain and service such an entity are few. Noncommercial institutions with the potential of integrating the library concept into their operation include the U.S. Agency for International Development, the U.S. Department of Agriculture, the International Institute for Applied Systems Analysis, the Food and Agriculture Organization of the United Nations, and the International Bank for Reconstruction and Development (World Bank).

The U.S. Agency for International Development has thus far exhibited little interest since their computer services unit is used mainly for data processing and has little capacity for research activity. Further, as indicated earlier AID does not have the qualified research and computer service personnel in large enough numbers to make effective internal use of such a library. A reassessment of the benefits and costs of staffing to maintain a library as both a service activity to developing country governments and universities is in order.

The U.S. Department of Agriculture has transferred limited portions of the MSU library, mainly the policy analysis language for its own internal use. A well developed library at USDA could become a national agricultural asset for use not only by USDA but by the land grant university system through the agricultural experiment station network. This network could also supply the library with its stock of routines components and models.

The International Institute for Applied Systems Analysis is a prime potential location for installation and further development of the library concept. IIASA has completed a feasibility study for developing its own software library and appears interested in moving forward with the concept to support in-house research programs, at least on a limited experimental basis. If successful this could become an international asset of great importance in a variety of fields and subject areas.

The Food and Agricultural Organization of the U.N. has recently turned away from quantitative analytical work and thus for the moment has little interest in the library concept. A reassessment of the

FAO position on quantitative approaches which includes the library concept at an appropriate time is in order.

The International Bank for Reconstruction and Development has already attempted a similar concept with some of their own models. They have not, however, recognized the need for an institutional structure surrounding such a library nor the need for comprehensive, standardized, detailed documentation. If World Bank were to develop the software library concept it could prove invaluable in conceptualizing and carrying out their economic missions and sector assessments. It would also be extremely useful in pre and post project appraisals and evaluations as well as being a service to host country project operations and evaluation agencies.

Other national and international agencies may be appropriate repositories for software libraries with either a general or special purposes focus. Further developing, testing, and use on an experimental basis of the library concept is necessary to determine the most appropriate organizational structure, operational processes, and institutional homes for long term viability.

Further Development of the General System Simulation Approach to Agricultural and Rural Development Planning

The general system simulation approach applied to planning and policy analysis for agricultural sector development has shown great promise by providing relevant information to decision makers for solving problems. Particularly important examples include the application of the approach in Nigeria and Korea. Though the Nigerian model was not designed for specific use by Nigerian policy makers, results from its use accounted for 60 pages of a Nigerian produced document entitled Agricultural Development in Nigeria 1973-1985, published by the Federal Ministry of Agriculture and Natural Resources Joint Planning Committee [4]. The Korean agricultural sector simulation model as reported in this book has been used extensively by Korean decision makers. The formal models for Nigeria and Korea are categorized by the authors as subject matter models of the agricultural sector capable of providing information relevant to the investigation of a fairly well defined set of problems confronted by agricultural sector development decision makers.

In addition, the approach lends itself to relevant disciplinary research, subject matter conceptualizations, and problem solving analyses in the much broader arena of rural development. The discussions in this regard in Chapter 2 begin to shown the potential for conceptualizing and relating the subject area and problem domains of health, education, transportation, rural industrialization, environmental quality considerations and a host of other sector, subsector, regional, program and project variables impacting upon the development of rural areas and their relationship to the rest of the economy and the rest of the world.

The substantial progress made in applying this approach to agricultural sector analysis can continue and expand at an accelerated rate. Central to success in further developing the approach is the avoidance of undue specialization on individual disciplines and their techniques.

This applies particularly to economics and its specialized quantitative techniques such as linear programming, input-output analysis, simultaneous equations based on probabilistic estimates of parameters from time series data and the like. It also applies to systems science and its specialized approaches such as control theory or dynamic simulations based on differential and/or difference equations. Progress will also be enhanced by avoiding subject matter models of little relevance to agricultural and rural development. Even subject matter models having to do with such crucial subjects as land tenure, agricultural marketing, energy or the role of women in agriculture can interfere with the development of broader comprehensive sector models. Such models can be constructed from components linked to model the domains of either well-defined problems or well-defined classes of problems faced by clearly identified decision makers and affecting well-defined groups of people in an economy.

In the process of developing and utilizing models and components for problem solving decision making in Korea, a number of subject matter models and components were revealed to require further substantial work. To the extent possible, with available resources, the theoretical and methodological shortcomings became the subject of disciplinary inquiry, primarily in dissertation research. Identification of the set of pressing potential problems to be solved in agricultural sector development guided the subject matter research and model development activity which in turn provided relevant and useful information for the solving of specific problems within the identified set.

The subject matter research and model development activity identified the theoretical and methodological research necessary to improve and extend the subject matter work. Successful accomplishment of the disciplinary research in turn improved the basis for the subject matter work and thus its ability to provide more useful and relevant information for problem solving activities. Thus a recognizable and complementary blending of relevant disciplinary inquiry, subject matter research, and problem solving activity was accomplished. Recognition of the differences and the proper role of each of these three types of research and model development activity allowed a balanced allocation of resources and efforts among the three areas of work and prevented overly enthusiastic focusing on any one to the exclusion of the others. It is necessary to keep this perspective in mind while examining further research opportunities in the general system simulation approach.

Needed Subject Matter Research

The job in Korea and more generally is not yet done but only well begun. Most developing countries do not have an adequate set of national agricultural accounts. Such accounts are crucial in developing agricultural sector models. The accounting identities on which they are based produce most of the "performance variables" with which decision makers are familiar and which are used by national planners of both the agricultural and nonagricultural sectors of the economy. Most systems could be designed to link data acquisition, processing, storage, and retrieval systems to analytical systems to provide more useful and relevant information for problem solving decision making. Recognizing the wide range and levels of aggregation required of analytical systems leads to the conclusion that the data systems must be extremely flexible in the types of data included and the levels and combinations of aggregations (or disaggregations) into which the data can be processed for use with the wide array of necessary analytical systems.

Data like models are capital stock. They represent one of several forms of archival experience and knowledge which when placed in the proper logical framework are valuable to present and future problem solutions. Data systems are required to collect, store, process, and provide data for a variety of unique and different uses within simple to complex analytical systems in one form or another in operational use the world over. Unfortunately most are barely adequate to inadequate and a great deal of work is necessary to develop generalized data-analysis-information systems and to institutionalize them as part of national investigative capacities. With such a fully integrated system, a model component used to project the behavior of an agricultural sector through time could, with very little additional effort, be designed to maintain and update its own data files, run its own consistency calculations on the data, process it in a variety of needed forms, and as part of the standard output produce the national agricultural accounts and other data normally found in published agricultural statistics yearbooks.

In both Nigeria and Korea the authors have been struck with the difficulty of developing components for dealing with nonmonetary, normative feedbacks from decision makers and affected people to planners, decision makers, and sector analysts. Perhaps this difficulty originates in the positivistic orientation of many economic analysts, systems scientists, and the cybernetists from whom the systems scientists have borrowed so much. On the other hand we are also struck with the necessity and importance of interaction between modelers and decision makers necessary to "model" these feedbacks at least informally.

Our experience has indicated both in developing and promoting the use of agricultural sector models that iteration and interaction are essential. As we and our host country colleagues have interacted with decision makers and affected persons the necessity to modify our models iteratively has been clear. This iteration and interaction has been helpful in defining and redefining the domains of both problem solving and subject matter models. It has also been a source of information, both normative and positive, and has yielded insight as to the decision making rules appropriately used in (1) modeling systems behavior, and (2) determining prescriptions for solving problems. This experience indicates a substantial need for more formal components to model such iterative interactions.

Needed Disciplinary Research

Disciplinary as well as subject matter and problem solving contributions are needed. For example, the output of an agricultural sector region or subsector depends not only on nondurable resources used and investments or disinvestments in durables, but also on the rate at which durables are utilized. John Maynard Keynes recognized this when he considered the "user costs" of varying the rate at which services are extracted from durables. He saw clearly that the output of economies, sectors, and subsectors depend on changes in durable utilization rates. User cost theory and the relationships between user costs and investments and disinvestments and, hence, growth and stagnation are not well developed in the discipline of economics. Model components are needed which will handle both user costs and investments and disinvestments if we are to project changes in agricultural production and in production capacities.

Economists have long been concerned with both monetized and nonmonetized values in exchange. They have also been concerned with total utility and welfare as well as exchange values. It is, however, difficult to deal with nonmonetized values in developing agricultural sector models to be used by decision makers to reach decisions. Contributions are needed from economists which will help model the monetary values and from humanists to help model the nonmonetary values important in making decisions concerning agriculture.

In addition, theoretical abstractions and methodological conceptualizations are sorely needed to better understand and project the determinants, the processes, the interactions and the consequences of technological change, institutional change, and human change. Our understanding about how technological change takes place could be much improved. Though economists have been experiencing some success with "induced innovation models" such models are too specialized in economics. They need to be supplemented by models explaining the origin of technical change, based on the knowledge of the biotechnical disciplines and models explaining the innovation of technical change based on the knowledge of humanist and sociological disciplines as well as economics. It will then become possible to develop subject matter models dealing with technological change far superior to those which have been created by economists alone.

The same approach is necessary with respect to models of institutional and human change although substantial contributions have been made recently under the rubric of "induced institutional change" and the "formation of human capital." In these cases, however, the contributing disciplines need to be expanded to include political scientists, education specialists, and psychologists.

Needed Problem Solving Research

One of the most important uses--in fact the ultimate use--of general system simulation models is to assist in solving practical problems. Since each problem requiring solution is unique and specific to a point in time and space, it is impossible to generalize about needed contributions for problem solving in the same way as for needed disciplinary and subject matter contributions. We can, however, indicate a major constraint in carrying out problem solving activity.

Building models of relevance for problem solving involves unique administrative requirements. Great administrative flexibility is required with respect to access to personnel, theories, methodologies, information, and models from a great variety of disciplines. Along with this flexibility is the requirement that the persons in charge of building and utilizing such models have administrative powers to command personnel and model contributions from the disciplines germane to the problem at hand. University departmental structures based largely on disciplinary distinctions are not well organized to supply the administrative flexibility and power required in modeling the domains of problems. Typically neither the administrative structure nor the administrative power to handle multidisciplinary problem solving projects are in place.

On the other hand, governmental agencies are not likely to possess the range of disciplinary competencies required for such activities. The enigma of the situation is that the universities have the range of disciplinary skills and competencies required but lack the administrative capacity to form them into problem solving configurations, while government does not have the necessary range of competencies at its disposal despite the wide array of pressing problems confronted and the large numbers of administrators on hand. It is this basic enigma which has made it necessary for government and universities to cooperate in doing problem solving agricultural development work and at the same time has made it almost impossible for government and the universities to succeed in organizing such problem solving research.

Potential Users of the General System Simulation Approach

The range of decision making bodies and others needing general system simulation models and components is almost endless. Some of the needs are for relevant disciplinary models, while other needs are for subject matter models and many are for specific unique problem solving models. In addition to the U.S. Agency for International Development which attempts to render technical assistance to agricultural planning agencies in the less developed world, many other U.S.

governmental agencies need such models and recognize this need by sponsoring and funding such research. In this connection the National Academy of Science recognized in the report entitled African Agricultural Research Capabilities [8] that it needs system models, both at the firm, subfirm, enterprise and subenterprise levels and at the sector and subsector levels; the latter models involve the production and marketing of modern inputs and the marketing, distribution and utilization of agricultural products, as well as the consequences of alternative agricultural policies, programs and projects. Another notable example is the National Science Foundation sponsorship of AGRIMOD, a computerized system simulation model of the U.S. agricultural sector designed for policy research and analysis [11].

The U.S. Department of Agriculture has been historically a developer and user of projection models or system simulation models longer before computerization took place. The USDA is now moving forward on computerized general system simulation models for long range projection and planning such as the National Interregional Agricultural Projection Model (NIRAP) [10] as well as shorter term policy analysis and outlook models [2].

At the international level, the International Institute of Applied Systems Analysis supported by the scientific communities of both eastern and western bloc developed countries is using general system simulation models in such subject matter areas as energy, interregional development, and food and agriculture.

The International Commodity Research Centers are increasingly recognizing the need for general system simulation models to understand such processes as photosynthesis, photorespiration, the nitrogen cycle, pollution of food chains, multiple cropping systems, and other applications. The International Bank for Reconstruction and Development has also engaged in development of general system simulation models at the sector, program, and project level. The need for such models by IBRD is likely to be even further evident when the bank succeeds in integrating its research and operations branches so that the research branch addresses itself to problems which the operations branch needs to have solved. Presently the bank's research and modeling program seems to suffer from use of models unduly specialized on economics and on the techniques of economists. Perhaps more general models based on contributions and techniques of other disciplines and focused sharply on the needs of the operations branch of the bank would be helpful in making the output of the research branch more useful and relevant.

In the United States various state governments are also interested in agricultural systems involving control of water, pesticides, environmental pollution, and land use. Agricultural system simulation models are also of value in modeling and solving problems of individual farmers. At Michigan State University a number of simple simulation models which can be operated by touch tone telephone from a farmer's home or office are being utilized. These include spraying routines, investment problem analyses, livestock feeding programs, and a host of other aides to specific problem solution.

Whenever such work is done a major reason for employing the general system simulation approach is to provide relevant and useful information to the decision maker to enhance his ability to solve the problems he encounters. The disciplinary research and subject matter inquiry and modeling within the general system simulation approach are designed to focus upon the domain of the sets of problems encountered by decision makers toward which the approach is directed. Each specific problem has its own unique domain and thus constant model development, updating, and reorientation must take place to provide the analysis and synthesis required to generate the information of use in solving specific problems.

FOOTNOTES

[1] Examples include Lee [6], in projecting technological change in Korea agriculture, with the use of CLASS delay routines for lags in the acceptance of innovation and CLASS table functions for the allocation of resources to education and extension work for the diffusion of innovations; Nweke [9], in his model of NIgerian forestry demand, used CLASS distributed delay routines to model the replacement needs for wooden structures, CLASS table functions for tracing projections of economic variables not amenable to simple algebraic equations, and CLASS demography components for population modeling. In addition, CLASS table routines, demographic components, delay routines, accounting components, and the policy analysis language were used by Watt, first, in developing a Michigan agricultural sector simulation model and, later, in his dissertation research [12] in developing a detailed production component for the Michigan agricultural sector study model. Finally, CLASS delay routines, table functions, and demographic components were used in the Jaske dissertation work [5] on livestock enterprise decision-making. The CLASS policy analysis language has been used in conjunction with two national agricultural models of the U.S. Department of Agriculture economic projections group. The first is a national framework model of the agricultural sector, the second an aggregate farm production model. Additional research projects, using CLASS library components, include a model for commercial fisheries in Michigan and a rubber industry model.

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