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9. ABSTRACT

This report investigates ways in which two important development planning mechanisms, agriculture and health sector analysis, could be used to further nutrition planning objectives.

The main objective of health sector analysis is to develop the specific information necessary to understand the exact way the various determinant factors--water supply, environmental sanitation, and the frequency and duration of illness interact to affect nutritional status. Once these relationships are known, the alternatives available for combating malnutrition must be submitted to a cost/benefit analysis. The purpose of agriculture sector analysis is to devise agricultural programs which achieve increases in food production while substantially reducing problems of underemployment, unequal income distribution and low levels of living. The report uses analyses from Portugal, Panama, Colombia, the Dominican Republic, India and the Punjab as illustrative models.

The following three elements are also included: a review and synthesis of the requirements for nutrition analysis and planning; determination of which nutrition analysis requirements could be fitted logically into the structure of sector analysis; and specification of possible extensions to existing sector analysis methodologies, in order to fulfill nutrition analysis requirements. There is also an extensive bibliography.

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INTEGRATING NUTRITION PLANNING CONCERNS INTO AGRICULTURE AND HEALTH SECTOR ANALYSIS

A Report Prepared for the
Agency for International Development
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September 1976

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PREFACE

This study was begun in July 1974 under the auspices of the Office of Nutrition, Technical Assistance Bureau, Agency for International Development. The main body of investigative work was done during the first year, and the results of this phase submitted to an expert panel of AID personnel, academic researchers, and officials of other international agencies in the field of development, for review. Critiques were received from this panel during the latter part of 1975, and provided many useful suggestions for revisions and improvements. This Final Report contains, as a result, a number of different approaches. It and the Preliminary Report submitted in July of 1975 constitute the final documentation of results completed under the contract.

We are indebted to Dr. Martin J. Forman, Director of the Office of Nutrition, who initiated the AID project under which the work was undertaken; to James A. Greene of the Office of Nutrition, who served as technical monitor during much of the course of the work, and whose guidance and criticisms were of tremendous value; to Drs. Lehman B. Fletcher and Richard E. Suttor, whose comments and discussions concerning the agriculture sector were extremely helpful; and to Drs. Joe H. Davis and John H. Daly, who provided many useful suggestions concerning the health sector. Although only one field trip was taken under this contract, other contracts took us to 14 countries on nutrition and agricultural planning assignments during the course of the research. Thus we have benefited from a considerable amount of field work during the period of this research, which has immeasurably enriched the work done under this contract.

The principal investigator for the project was Dr. George V. Poynor. Other personnel who took part in the research were Dr. Orville Goering; Dr. Arthur J. Dommen; Ms. Hope E. Sukin; and Ms. Margaret S. Andrews. We are hopeful that our conclusions will be of value in making agriculture and health sector analysis more useful in attaining nutrition objectives in the developing world.

September 1976

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I. INTRODUCTION

Purpose and Scope of Work. Research into malnutrition and its causes in the developing world has shown that there are numerous dimensions to the problem. Nutritional status is determined by a complex interaction involving food supply, income, health status, environmental conditions, education and a host of other interrelated factors.

Because of this multi-dimensionality, today it is recognized that in order to plan effectively for combatting malnutrition, we must have an expanded nutrition planning concept. Since the determinants of malnutrition operate in many sectors, it is clear that the focus for nutrition planning must be multi-sectoral.

The principal purpose of the work reported here has been to determine ways in which two important development planning mechanisms, agriculture and health sector analysis, could be used in order to further nutrition planning objectives.

The scope of work included the following elements: (1) a review and synthesis of the requirements for nutrition analysis and planning; (2) determination of which nutrition analysis requirements could be fitted logically into the structure of sector analysis; and (3) specification of possible extensions to existing sector analysis methodologies, in order better to fulfill nutrition analysis requirements.

The Nutrition Problem. Malnutrition is one of the most serious and widespread problems in the world. In the low income countries its presence is seen in a dramatic and widespread

malaise affecting large percentages of the population. The most significant impacts of malnutrition in these developing countries are on the health and well being of young children. Because of his rapid growth, and because of critical developmental processes in the young child, adequate nourishment is all important during the first few years of life. It is in precisely this period that malnutrition is most severe in the developing world. Since the health of the children of a society is an important factor in determining the quality of its future human resource base, whatever affects their development and health will affect the health and development of the nation in which they live.

Direct and indirect measures of child malnutrition in developing countries show alarmingly high proportions of the child population to be malnourished. A common direct measure for malnutrition in children under five years of age is body weight. Statistics show that in most developing countries, 2-4 per cent of the children under five years of age have body weights of less than 60 per cent of Standard body weight for their age. This is termed third degree malnutrition. Another 15-25 per cent of children under five typically suffer from second degree malnutrition, evidenced by body weights less than 75 per cent of standard body weight. And an additional 40-50 per cent of this child population falls in the category of first degree, or mild malnutrition, determined by a body weight of between 75 and 90 per cent of standard body weight for a given age.

Indirect measures of malnutrition include food consumption statistics, and health statistics concerning child morbidity and

mortality. The figures shown in Table 1. indicate severe deficits of both calorie and protein intakes for the population surveyed. While these figures are only for one country, we could as easily include tables showing similar results for another twenty. We have chosen to use the Dominican Republic for a particular reason. For the past six or seven years the economy of that country has, by all of the traditional measures of economic progress, been in a period of economic boom. GNP has been growing at an average annual rate approaching 10 per cent. Total investment in the economy has been growing at a much more rapid pace. Average per capita income has been rising. This situation is in contrast to the 10 year period beginning with 1960, in which the economy was relatively stagnant.

A survey of pre-school children in the Dominican Republic taken in 1969 showed only 25 per cent to be within normal weight ranges, with 49 per cent having first degree malnutrition, and 23 and 4 per cent being in conditions of second and third degree, respectively.[1/] Nutritional assessment carried out as a part of a 1974-75 health sector assessment in the D.R. showed no evidence of improvement in the levels of malnutrition, even with definitely improved overall economic conditions during the period after the baseline survey of 1969. This health sector assessment stated that malnutrition may even be the major health problem in the Dominican Republic.[2/]

1/ W. H. Sebrell et al., "Nutritional Status of Middle and Low Income Groups in the Dominican Republic," Archivos Latinoamericanos de Nutricion, Vol. 22, Numero Especial, July 1972.

2/ Health Sector Assessment for the Dominican Republic, USAID, Santo Domingo, 1975.

TABLE 1

DOMINICAN REPUBLIC

PER CAPITA CONSUMPTION OF CALORIES AND PROTEINS BY INCOME GROUPS*

Food Item	RD $0-4.99** Calories	RD $0-4.99** Protein (g)	RD $10-14.99 Calories	RD $10-14.99 Protein (g)	RD $20-24.99 Calories	RD $20-24.99 Protein (g)	RD $25-29.99 Calories	RD $25-29.99 Protein (g)
Rice	36.40	7.20	473.20	9.57	607.88	12.02	684.32	13.54
Pasta	27.44	0.82	30.87	0.93	34.30	1.03	30.87	0.93
Beans	97.73	6.38	107.84	7.04	111.21	7.26	134.80	8.80
Cassava	21.21	0.11	20.20	0.10	37.37	0.19	48.48	0.24
Beef	19.80	1.51	31.68	2.42	77.22	5.89	97.02	7.40
Chicken	4.68	0.50	5.85	0.63	28.08	3.02	25.74	2.77
Pork	5.58	0.40	13.02	0.93	18.60	1.33	29.76	2.13
Sausage	3.79	0.11	11.37	0.34	34.11	1.02	34.11	1.02
Eggs	--	--	1.95	0.15	3.25	0.25	9.10	0.69
Milk	1.30	0.07	3.90	0.20	5.85	0.30	9.75	0.50
Sugar	99.84	--	218.80	--	318.72	--	384.00	--
Oil	132.60	--	243.00	--	318.24	--	397.80	--
Plantain	85.09	0.75	202.02	1.78	259.35	2.28	--	--
Bread	67.54	2.05	101.31	3.07	135.08	4.09	194.95	5.91
TOTAL	603.00	19.09	1465.01	27.16	1989.26	38.68	2080.70	43.93
Per cent of Population	6		32		42		48	

*Unpublished tabulations from "Income and Expenditure Survey of 1969," Central Bank of the Dominican Republic.

**Monthly income per capita.

Infant mortality statistics taken in 1974 showed that 127.9 children died in infancy (within the first year of life) for every 1,000 live births. An additional 19.6 of these children died between the ages of one and four. These figures were four times as high as the corresponding figures for the United States for the year 1968. Although the causes of death in infancy and early childhood are varied, malnutrition is a direct or contributing factor in most of these deaths in the Dominican Republic.[1/]

While aggregate economic statistics do not correlate well with the nutritional problem in the Dominican Republic, it is possible to explain the problem by examining disaggregate data regarding food consumption, income distribution, food habits, health and environmental problems. This kind of analysis in a number of countries has led to the development and use of a conceptual model for diagnosing nutrition problems in terms of their socio-economic causes. The model, shown in Figure 1. on page 6, was first published by Alberto Pradilla et alia in [18, 1975].

A Conceptual Model for Nutrition Analysis and Planning. The model shown in Figure 1. can serve as a conceptual framework for nutrition analysis and planning. It shows two fundamental sets of factors to be principally at cause in malnutrition: (1) factors which affect the quantity and quality of food ingested; and (2) factors which affect the biological utilization of nutrients.

Among those factors which affect the quantity and quality of food consumed are: (1) income; (2) the food habits of the consumer, including those which affect the kinds of foods eaten or proscribed, the intrafamiliar distribution of food items, methods of food

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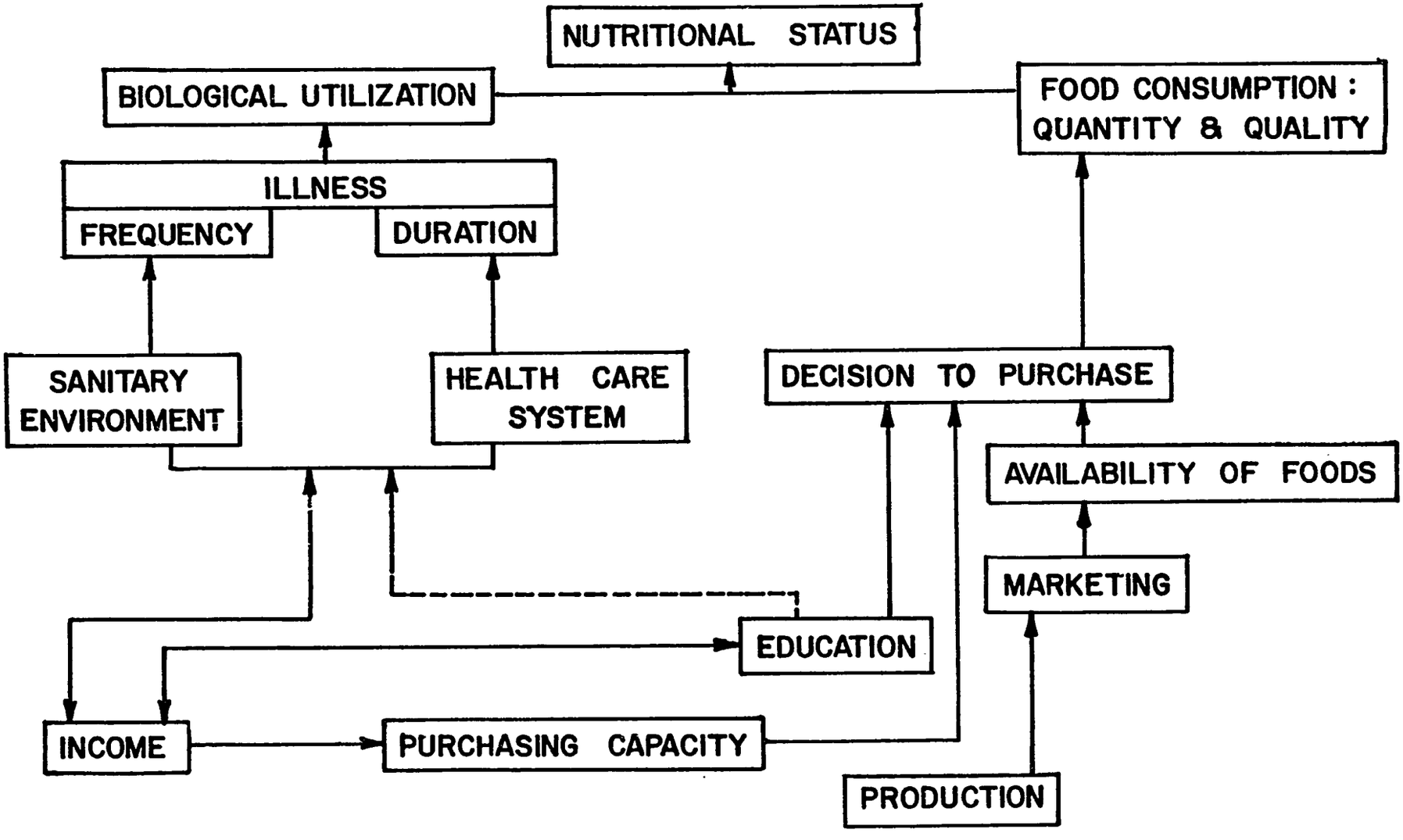
1/ Puffer, Ruth Rice and Carlos V. Serrano, Characteristics of Mortality in Childhood, PAHO, Washington, D.C. 1973.

FIGURE 1.


NUTRITIONAL STATUS
BIOLOGICAL UTILIZATION
FOOD CONSUMPTION : QUANTITY & QUALITY
ILLNESS
FREQUENCY
DURATION
SANITARY ENVIRONMENT
HEALTH CARE SYSTEM
DECISION TO PURCHASE
AVAILABILITY OF FOODS
MARKETING
EDUCATION
INCOME
PURCHASING CAPACITY
PRODUCTION

preparation, and breast feeding behavior; (3) the availability of food items for purchase, and the relative prices of food items. These are in turn determined by levels of education, and by decisions within the food production system.

Perhaps one of the most difficult systems to analyze and control is the economic subsystem which relates purchasing power to food production. The equilibrating mechanism in this system is the economic law of supply and demand, or that set of forces which balances the consumer's demand for food with the producer's supply, through price bidding in the market place. An additional complication is introduced in view of the fact that in most developing countries a large percentage of the population consists of families who both produce and consume food. Traditional policies available to influence food supply and demand (producer credit, extension services, crop breeding, irrigation and commodity price policies) must be evaluated with respect to their influence on producer income as well as the more usual analysis of impact upon food availabilities. Likewise income policies designed to generate employment or to effect transfer payments need to be examined with respect to their impact on food production when better nutrition is a specifically stated objective.

The efficient utilization of the food consumed is in part conditioned by the quality of the food eaten. For example, foods not containing a balanced proportion of the amino acid groups which make up the protein content of food cannot be utilized with the same efficiency as those which do contain amino acids in proper proportions. This means that in many cases the actual utilizable

protein content of food is lower than the estimates provided by food consumption data.

The biological utilization of food consumed is also strongly conditioned by the occurrence of infectious disease. The frequency of occurrence of such disease is largely an environmental matter, with the availability of potable water, adequate means of environmental sanitation, and preventive health measures playing key roles. The duration of illness is partly a function of the nutritional status of the individual, and partly a function of access to, and affordability of, curative health services.

The model under discussion is not exhaustive in its treatment of the causes of malnutrition, nor does it attempt to illustrate all of the many interactions of the various determinant factors. Rather it is intended to serve as a schematic, or conceptual, framework, which can be used to direct problem definition and analysis of nutrition problems. In spite of its simplicity, the model seems to fit the observations of a wide audience of researchers and program-oriented professionals whose work relates to nutrition, as a way of representing the essential determinants of nutritional status, for the purpose of planning nutrition and nutrition-related programs.

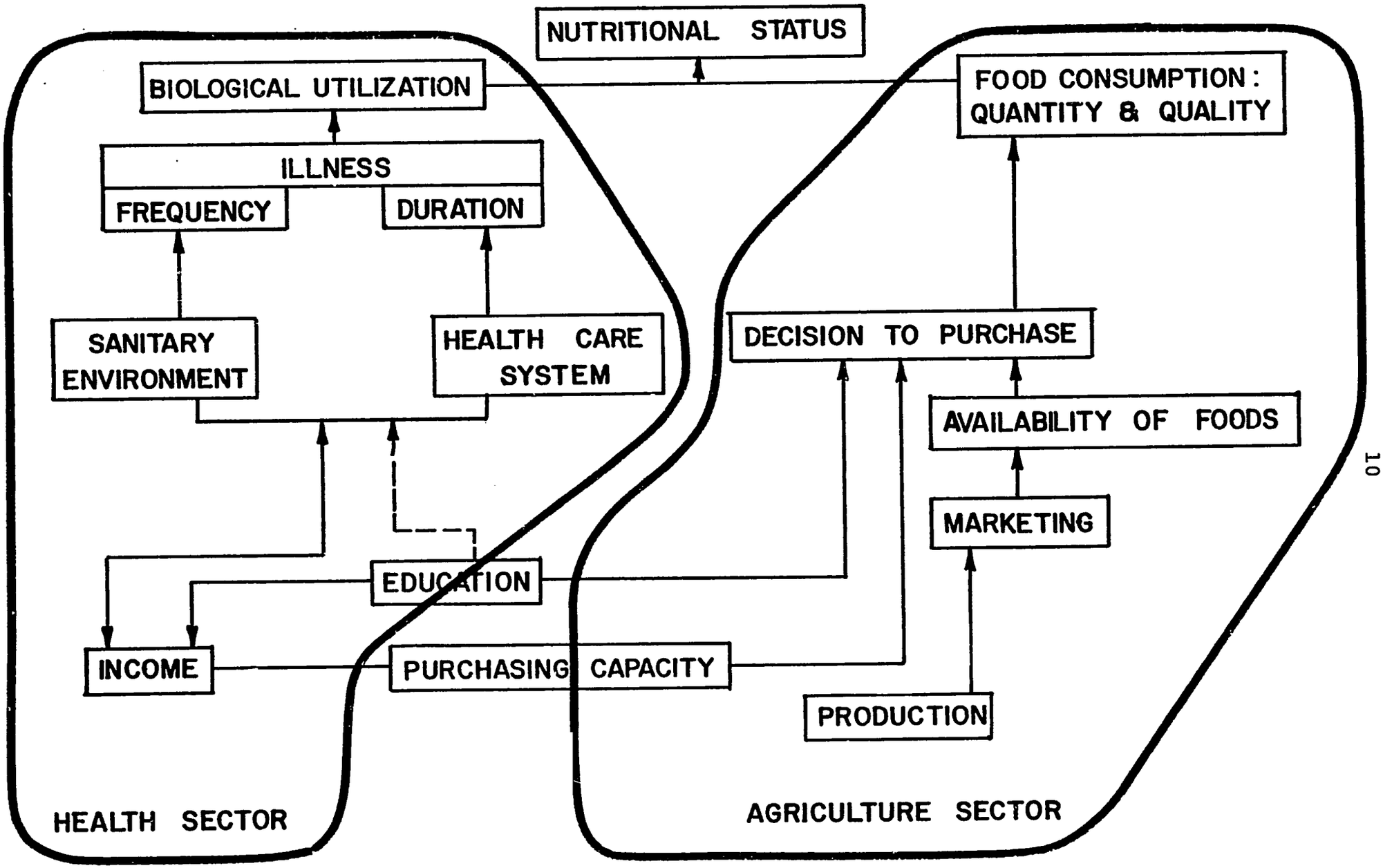
A distinct advantage of this approach is the breadth of view. Because of its great complexity, the nutrition problem can be viewed from many perspectives, and consequently can be defined, for the purposes of research and analysis, planning, and program design, in many different ways. The way in which the problem is initially defined, in a given situation, naturally influences the kinds of

analytical methods and research tools used in investigating the problem, the data required to carry out the analysis, and ultimately the kinds of program alternatives selected.

In Figure 2. the conceptual nutrition planning model discussed above has had those subsystem models corresponding to agriculture and health planning highlighted. Although it has not been the case traditionally to treat environmental sanitation as a part of the health sector, some developing countries, among them Costa Rica, Honduras and Nicaragua, are now beginning to do so. Problems of the environment, such as the lack of potable water and sanitary means of waste disposal, have been shown to correlate highly with health problems such as diarrheal disease in infants and small children, and the highest incidence of such problems usually occurs in rural or peri-urban areas, normally beyond the influence of urban water and sewage systems. Since ministries of health normally operate clinics and other health services in the areas of high incidence of these illnesses, it is logical to add the provision of low-cost water and waste disposal services to their function. Thus in Figure 2. the system module representing environmental concerns is included within the health sector.

In Figure 3. the conceptual model has once again been annotated to show points where different kinds of system intervention can be contemplated in nutrition planning. Only a few of the more important interventions are illustrated, but those shown again indicate the wide variety of activities which must be included under nutrition analysis and planning.

FIGURE 2.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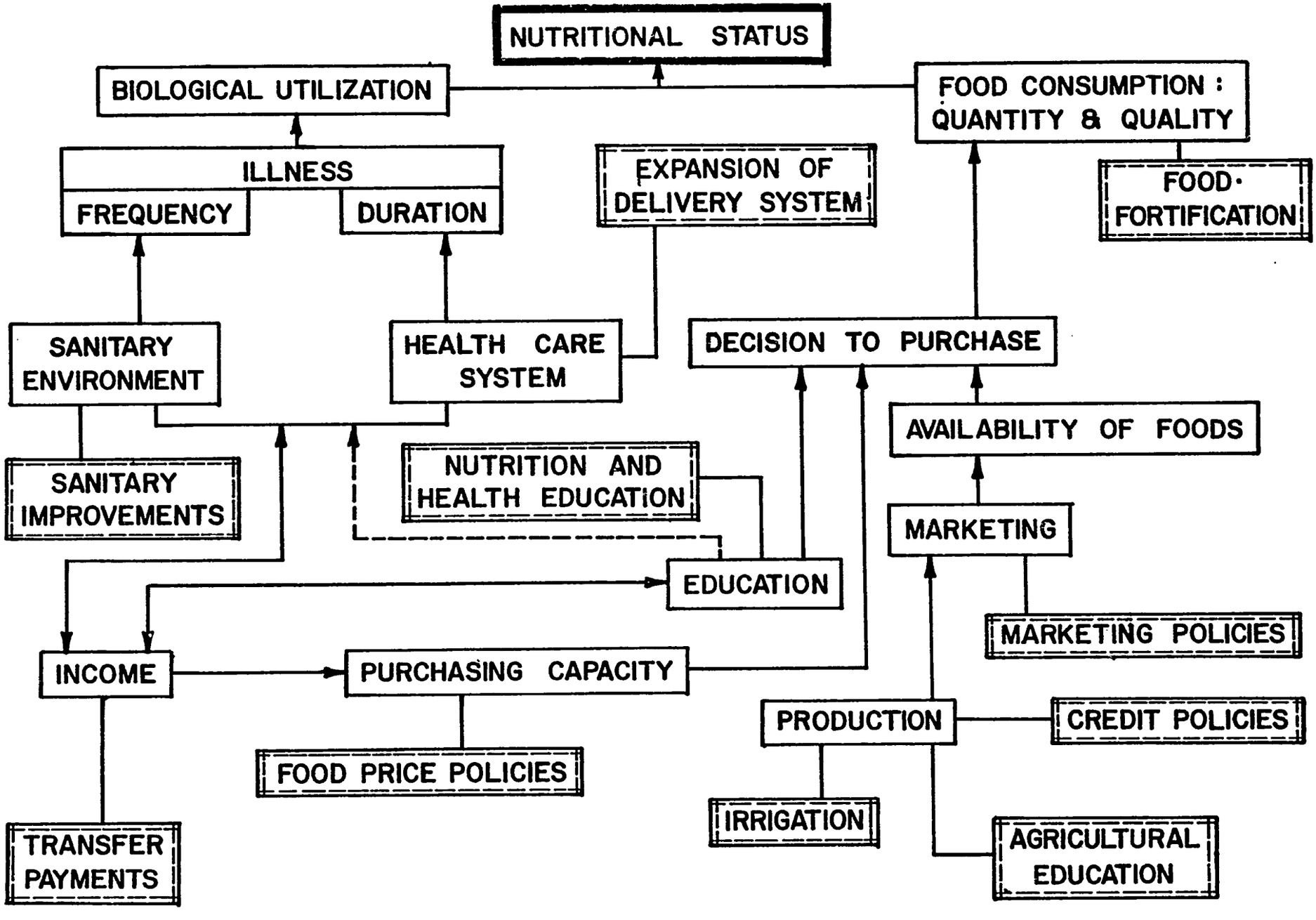
MARKETING
EDUCATION
INCOME
PURCHASING CAPACITY
PRODUCTION
HEALTH SECTOR
AGRICULTURE SECTOR

FIGURE 3.


NUTRITIONAL STATUS
BIOLOGICAL UTILIZATION
FOOD CONSUMPTION : QUANTITY & QUALITY
ILLNESS
FREQUENCY
DURATION
EXPANSION OF DELIVERY SYSTEM
FOOD FORTIFICATION
SANITARY ENVIRONMENT
HEALTH CARE SYSTEM
DECISION TO PURCHASE
AVAILABILITY OF FOODS
SANITARY IMPROVEMENTS
NUTRITION AND HEALTH EDUCATION
MARKETING
EDUCATION
MARKETING POLICIES
INCOME
PURCHASING CAPACITY
PRODUCTION
CREDIT POLICIES
FOOD PRICE POLICIES
IRRIGATION
TRANSFER PAYMENTS
AGRICULTURAL EDUCATION

The Future of Nutrition Planning. Evaluations of the results of development programs have shown that nutritional ends will not automatically be met by addressing traditional development goals. In fact, the reverse may be true in many cases. Many governments have come to realize this, and a few have already come to the decision that nutrition demands, and deserves, attention as a national development goal, given a high level of emphasis as are more traditional goals.

This has important implications for nutrition planning. First of all, it implies opportunities for nutrition planning to be done at a sufficiently high level that the multi-sectoral aspects of the problem can indeed be dealt with in an integrated fashion. Several examples of attempts to do this already exist. Notable among them are Chile, Costa Rica, and Pakistan.

But there are serious responsibilities and new challenges contained in this opportunity. Nutrition planning in the broad sense we have been discussing here is very new. There is little in the way of a theoretical basis for the development of integrated nutrition plans. Although the conceptual framework we have outlined includes most of the areas of importance identified in several decades of nutrition research and program implementation, it falls far short of being an ideal framework for dealing with the problem. The relative importance of the various determinants is not known with even approximate certainty.

Answers to questions concerning issues such as these are not likely to come from nutrition research as it has been traditionally conceived. They are more likely to come from broad, program-oriented research of an operational nature, including within its scope all of

the major determinants of malnutrition. Because of the difficulty in providing controlled conditions for experimentation in research of this type, the kinds of investigation required more closely parallel economic research than they do nutrition research.

Because of the broad nature of this kind of inquiry, multi-disciplinary approaches will have to be used. Professionals in disciplines which have an important nexus with nutrition will have to learn how their traditional investigations relate to nutrition objectives, as well as the importance of various other disciplines in nutrition planning. National planning efforts will have to be enlarged to include nutrition concerns, and national planners will have to learn new methods for analyzing nutrition problems at the national level. Since research and planning efforts in those sectors important to nutrition planning must be coordinated or managed from some central point, there will be a need at that center for technical and managerial expertise which will permit direction of activities along a number of broad fronts. The orientation must not be toward any single discipline, but must include enough technical familiarity with the basic ideas, problems and techniques in all of the research areas to permit close coordination and collaboration with workers in those areas.

This approach carries with it certain implications for the kinds of academic or extra-academic preparation which must be sought or brought into being in order to train people who will be responsible for the national-level direction of nutrition planning. The training must be multi-disciplinary, must involve a program-oriented focus, and must combine technical training with training and experience in the use of management skills.

Sector Analysis. What is sector analysis? The answer to this question is difficult because of the relative youth of the sector analysis discipline. An attempt to provide a definition must derive in part from a deductive analysis of the kinds of development concerns which are typically faced, and what end results are expected from planning efforts. In addition a part of the answer comes from analysis of existing studies which can be identified as attempts to address these concerns. Both approaches bring important insights. The deductive approach is important because it focuses attention on the key relationships which exist between goals and means, and helps to develop the analytical methods which will link them. On the other hand, analysis of existing studies is necessary because it teaches what practitioners have been able to accomplish, faced with the realities of time and resource pressures, and working from an existing base of information about the sector and its operation.

There is a substantial literature concerning agriculture sector analysis, and a small but growing one concerning efforts in health and education to employ the same approach that has brought fruit in agriculture. But little has been published so far concerning the concept of sector analysis *per se*. There are certain structural features which can be discussed independently of the individual sectors, and it is worth while pointing these out in this overview. Such an overview must of necessity be qualitative and somewhat general, but can nevertheless be helpful in leading to an understanding of what sector analysis is, what it purports to do, and what its limitations are likely to be. Sector analysis, like many other approaches to development planning has its roots in

the desire to accelerate social and economic development. Since social and economic processes have long managed to operate in a reasonably stable manner without this kind of analysis, it can be argued that there is no inherent need for it. The counter-arguments can be made simply in terms of development goals.

There is a sense of tremendous urgency in the developing world concerning social and economic development. The poorer nations, aware of growing problems of unemployment, low incomes, inequitable income distribution, and lacks of needed social services, are adopting national development goals which emphasize measures of social and economic progress and which call for much more rapid changes than have been experienced in national development in the past.

Thus development resources must be allocated, not only in an efficient manner as measured by outputs and inputs, but also in such a way that a multiplicity of goals is served. This complicates the problem of development planning more than it might seem. The principal complication follows from the fact that most development goals are external to the social and economic systems which are to serve those goals. And in order for these systems to be responsive to externally derived goals, they must, to some extent, be <u>managed</u>.* Although they may well perform stably without management, performance will in general not be directed toward satisfying objectives that are decided upon independently of the systems themselves.

This requirement of sector management, once accepted,

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*We are not using management here in the sense of having complete control, but rather in the sense of being able to assert influence to the extent that system behavior can be modified in predetermined directions.

leads to a series of conclusions. The first and most important of these is that the behavior of the sector must be understood well enough that the decision-makers 'managing' the sector are enabled to estimate how sector behavior is related to development goals, in order to be able to choose policies and programs which will produce satisfactory results in terms of these goals.

Research into complex systems (most people would agree that any given sector of a society is a complex system) has shown that intuitive understanding of the behavior of such systems is a rare occurrence. The term 'counter-intuitive behavior', in common usage today, was coined precisely because of the prevalence of incidents in systems research where system behavior runs counter to what one's intuition says it should be.

But if our intuition fails us in understanding sector behavior, then our only recourse is to develop and rely upon formal analytical methods for aiding our intuition. Where do these methods come from? From theoretical investigation: research. The ultimate goal of development planners, however, is to use such knowledge to influence sector behavior. Therefore, we need to be able to use the results of theoretical work as they are available to help us in examining actual and proposed policies and programs.

We have thus defined a spectrum of activities, ranging from theoretical investigation aimed at producing formal

methods for explaining sector behavior; to the application of these methods, aimed at producing information about specific policies and programs in specific sectors. It is this spectrum of activity that we shall be concerned with when we talk of sector analysis, and for the moment this is as much of a definition as we shall give. There is currently some debate regarding whether research activities should be called sector analysis activities or not. If not, the line of demarcation between sector analysis and research becomes somewhat fuzzy, if not arbitrary. If included, activities not part of the decision-making apparatus proper (research activities) are labeled as sector analysis. We see no end to be served in this document by taking any particular stance, and so we shall leave that choice to the reader. We will present for consideration quotes from two able writers on sector analysis.

> "The ultimate aim of sector analysis is its practical application to...sector development problems and policy alternatives. Particular projects can usually be classified under one or the other of the following types:
>
> 1) those intended to produce results of direct interest and relevance to decision-makers;
>
> 2) those intended to develop or test new methods and approaches or to learn more about...sector growth and development policies.
>
> LDC and aid personnel usually are more concerned with the first type while research and university professionals in developed countries are more interested in the second type. Over time, methods developed and knowledge gained in projects of the second type will find practical application in the

first type. The dynamic evolution of methods from experimental to operational and of knowledge from theoretical to applied is the key to sustained and accelerated progress in sector analysis. The ultimate dependence of useful applications on improved methods and increased knowledge should be fully recognized in a programme designed to expand the application of sector analysis."1/

"The analysis of social phenomena or events can be looked upon as the first logical step in a cyclical process under which those phenomena are treated in terms of the following steps: (1) analysis; (2) planning or strategy; (3) program or project design; (4) implementation; (5) evaluation of the analysis, strategy and implementation in the light of implementation results; (6) a subsequent and fresh analysis utilizing updated or more recent data, as well as the results of the evaluation, with the subsequent analysis having broader scope and greater depth."2/

"Perhaps this perception of analysis in the general context of social development can be supplemented with some comments concerning analysis in the similarly broader context of inquiry into and reflection about social phenomena. The type of analysis considered here is predominantly empirical in nature and can be looked upon as standing between theory and policy. It will draw on theory and lead to policy, but must be clearly distinguished from both. It will avoid research the main intent of which is to test theories or hypotheses of no perceived immediate importance for policy. It is policy oriented in the sense that it concerns itself with current or anticipated social problems. And it will avoid being pre-cast into policy through premature adoption of conclusions that are for some reason accepted or preferred before the analysis is carried out.

1/ Lehman B. Fletcher, Needs and Opportunities for Agricultural Sector Analysis in Developing Countries, paper presented at FAO Meeting to plan an international program of cooperation in agricultural sector analysis, Rome, Jan 8-10, 1975.

2/ Brandon Robinson, On Methodology for Education Sector Analysis, AID 1975.

> Finally, as well as being logically prior to policy, sector analysis is open and welcoming with respect to the disciplines it employs. For example, it does not view itself as economic analysis, nor, for that matter, sociological analysis. And it avoids such identifications, among other reasons, because it will not pre-cast development problems or limit itself to the issues in the manner in which these disciplines and other social sciences are inclined to pre-cast problems and pre-select issues. On the other hand, sector analysis will draw on any discipline that provides concepts and techniques which can contribute to the achievement of development goals. Obviously, the discipline of economics plays a fundamental role. In sum, sector analysis is multi-disciplinary in nature with respect to the theoretical and procedural tools which it employs."1/

While sector analysis deals with issues, policies and programs at the sector level, ultimately the implementation and evaluation of these policies and programs takes place at another level, which for convenience we shall call the 'micro level'. The transformation of statements from one of these levels to the other is a fundamental task of sector analysis.2/ The following diagram summarizes schematically this function of sector analysis (Figure 4.).

Note that statements regarding the structure and status of the micro-units that make up the sector are aggregated into similar statements about the sector. These statements are used in conjunction with statements concerning other sectors and their interactions to arrive at information which

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1/ Brandon Robinson, On Methodology for Education Sector Analysis, AID 1975.

2/ We are using the term 'statement' in a rather loose and comprehensive manner. Under our usage an economic model would be accepted as a statement, as would be a series of numerical projections of system variables.

can be used to evaluate sector policy and program alternatives.

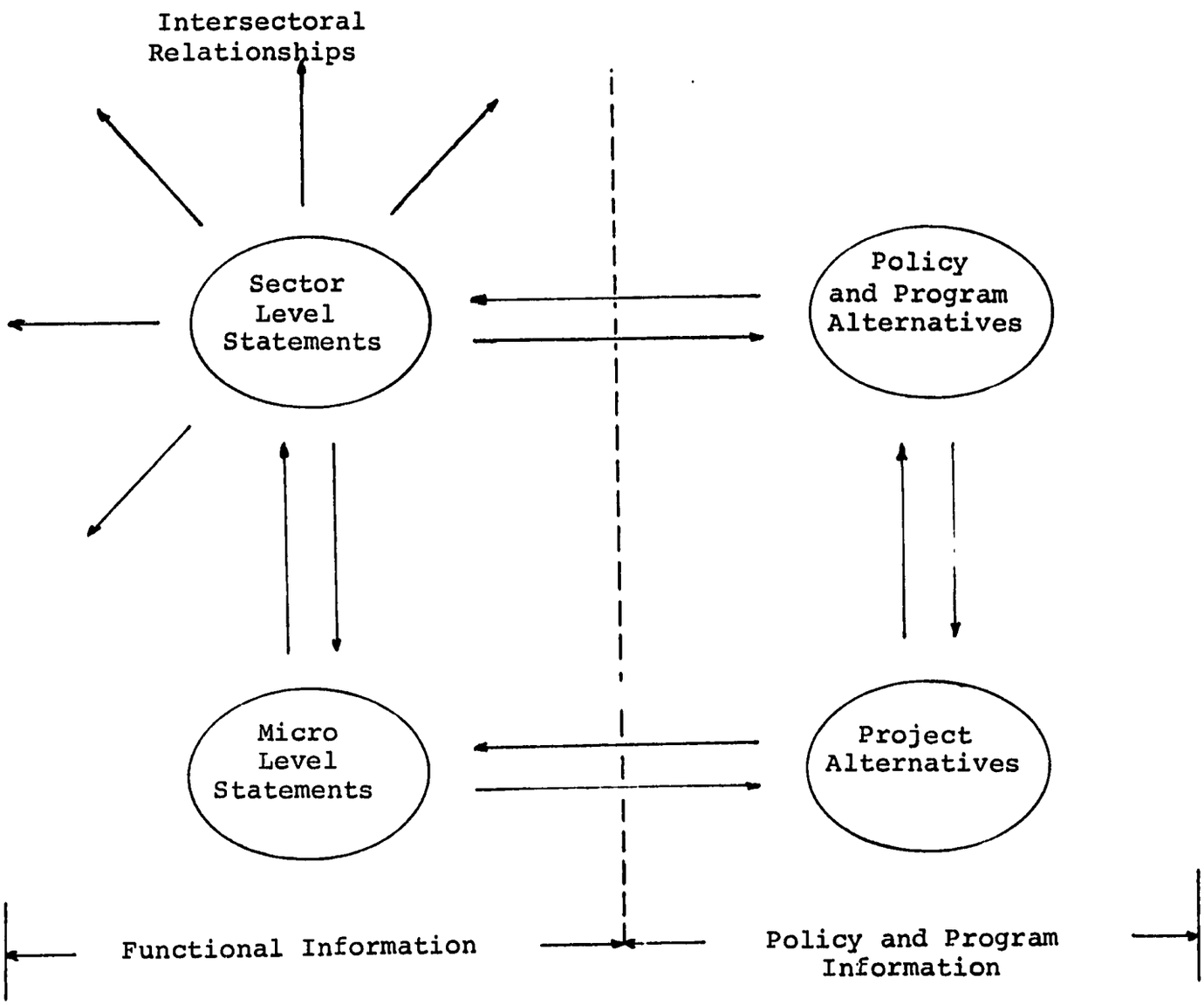

Figure 4. Schematic diagram of relationships in sector analysis

It should be mentioned here that the effect of intersectoral relationships on policy and program alternatives is sometimes viewed as a two-level process in itself, with sector analysis *per se* concerned solely with intrasectoral activities and relationships. This compartmentalization can lead to ill-specified analytical results. It also allows for standing conflicts in goals, objectives and programs among various sectors. Inasmuch as it is practicable, sector analysis should include intersectoral statements.

At the other extreme of our diagram, sector policy and program decisions eventually evolve into sets of concretely specified projects, most of which are implemented at the micro level. As before, there are different views concerning whether or not project analysis is a part of the sector analysis process itself, or should be viewed as a separate entity. Conceptually this presents no problem. The two kinds of activity abut nicely. Decisions, however, should flow from the sector level to the project level, but in practice the reverse often occurs, with sector studies being used to justify project activity which has already been decided upon.

The performance of sector analysis produces the need for information, and is in turn fueled by information. The information that is desired is information that holds out the prospect of revealing the shape and operation of the system it is hoped to influence or control. Information is not reality, but gives a clue to reality. Analysis on the basis of faulty

or partial information, therefore, can lead to wasteful or counter-productive results if it is equated unthinkingly with the real system over which policy-makers are striving to exert influence.

In order to be able to speak a little more precisely about the relationship of information to real systems and by extension sector analysis, we shall distinguish three levels. Following the analogy of digging down to underlying reality from superficial phenomena observed on the surface, we will deal with these three levels by beginning at the highest level, which we will call the descriptive level.

The descriptive level consists simply of observable attributes without necessarily any connection between them. It is simply what we see. We look at a village. We see people plowing fields. We note that it has recently rained. We see women carrying water, children tending buffalo. On inquiry we find out what the asking price for a measure of wheat is, how much wheat the people in the village are eating, who is working on whose fields, and for what wage. The number of separate pieces of information at this level is practically infinite, and unless we have some preconceived idea of how to organize them, think about them, compare them with others, they are totally useless to us.

The data in and of themselves give little or no insight into the behavior of the system or sector, even less insight into how sectoral behavior might be altered in a particular direction by purposive action (although they suggest intuitively

certain ameliorative actions attractive for their simplicity -- lower the price of wheat, legislate a minimum wage, divide up the land -- which, if actually implemented, might produce disastrous consequences). For that kind of information, we must proceed to an examination of the second level of integration of information.

The second level of information we shall call the <u>structural</u> level. Information at this level consists of information about how the separate pieces of information at the first level are related to one another. In other words, information about structure. This information lies one level deeper than the first kind. We do not observe it at first hand, but instead have to apply certain theoretical constructs to derive it. Examples are our expectation that as price rises more will be offered for sale and less demanded for purchase, and our expectation that as the quality of the diet improves the incidence of disease will decline. Constructs such as these, together with the primary data and certain assumptions that we make, allow us to frame tentative hypotheses about parts of the system's behavior, both in terms of the direction and magnitude of changes in that behavior.

To predict the behavior of any part of the system with any degree of confidence, however, we must have the whole system 'in view.' In view has been written in quotation marks because, of course, we can never actually see the system, but only its outward manifestations (the rain dries up, the crop

fails, the farmers sell their land, seek work for wages, migrate to the city, etc.). It is at this, the deepest level that we can speak of the policy, or control level. It is here that information from other sources, can be combined to produce policies or control mechanisms to move the behavior of the system in a desired direction. Understanding of the policy, or control, level implies that the information has already been filtered through the other two levels; all extraneous information has been selected out, and the causes and effects of one variable on another have been identified.

Nutrition Planning and Sector Analysis. We have in this introductory chapter taken a look at the determinants of nutritional status, and have shown that they reach into both the health and agriculture sectors in a number of ways. We have discussed a conceptual framework for viewing nutrition planning requirements which relates these determinant factors to program interventions of various types. And we have provided an abstract overview of sector analysis.

In the next two chapters we will continue to explore the relationships between nutrition planning and sector analysis, treating the health and agriculture sectors separately, and probing more deeply into methodological concerns, in an effort to find ways that nutrition concerns can be addressed through the use of sector analysis in health and agriculture.

There are, however, a few conclusions of sufficient generality and importance that they merit mention at the outset. The first, which we have already alluded to, is that the problem of

malnutrition in developing countries is of such magnitude and import that nutrition deserves attention as a national development goal. It is important in this regard that nutrition planners make serious efforts to have nutrition incorporated as a goal in national planning efforts. This step may even be a necessary condition to the successful incorporation of nutrition into sector planning in many countries.

A second observation is that nutrition planning has reached the point where the nutritionist's skills are not sufficient for carrying out the entire spectrum of effort required. The nearest analogue to the situation that we have been able to find is the situation that spawned the use of operational research methodology in the military in that period just before and during the second world war. A curious fact, or so it seemed at one time, was that teams of scientists totally unfamiliar with the intricacies of military science, totally unexperienced in the systems of warfare, could produce viable and unexpectedly useful solutions to problems that completely baffled the trained professional. We suspect that this multi-disciplinary approach will help provide the fresh, unhampered thinking that is needed to provide new solutions to the problem of nutrition planning.

And finally, the importance of continuous analysis and evaluation of nutrition problems cannot be over-emphasized. Too often the analytical apparatus is only revived when projects need to be justified, giving rise to hurried, poorly designed, and badly directed analytical efforts.

The analytical basis for nutrition planning requires work in four areas of endeavor: (1) analysis and documentation of the extent and severity of the problem of malnutrition; (2) explor-

ation of the causes of malnutrition, both proximate and socio-economic, to determine their relative importance for investment of resources; (3) analysis of alternative types of interventions for combatting malnutrition; and (4) analysis of the problem of overall allocation of resources, in order to determine priorities for investment.

There are both institutional and methodological concerns that need to be addressed at the central level of nutrition analysis and planning, before best use can be made of sector analysis efforts in health or agriculture. A first condition is that there must be some central nutrition planning body to coordinate nutrition analysis and planning. This body can function either as an analytical unit, or it can assume merely a managerial and coordinating role, but its existence is essential to effective national planning for nutrition.

It is important that there be an overall methodological approach to nutrition planning, well specified and understood by all levels of participation in the nutrition analysis and planning function. The approach that we are recommending here follows the four areas of analytical activity mentioned above.

1. Analysis of extent and severity of malnutrition. Information concerning the extent and severity of the nutrition problem typically is generated within the health sector. It comes from three principal types of sources: (a) operating statistics concerning delivery of health services; (b) small scale studies of nutritional status and/or nutrition-related illness, usually made at the village or family level; and (c) larger surveys of nutritional status, either taken at the regional or national level.

At the level of national nutrition planning, perhaps the simplest approach to building up a national data base concerning the extent and severity of the problem is to use mapping techniques. A mosaic can be built up using information from different studies of different types. At this level the process of analysis and documentation needs to be continuous, even though the data used may come in sporadically from different sources. Maps of different scales can be used to represent the problem at different levels. In most countries maps produced through the use of aerial photography are available with a great deal of detail, allowing actual pin-point location of dwellings, farm land, clinics, health posts, etc. Micro-level studies can be summarized at this level of detail, and later fitted into larger scale maps like the parts of a jigsaw puzzle. In this way a picture of the nutrition problem on a geographic basis will gradually emerge. Future studies can be directed on the basis of information summarized in this manner, either to fill in parts of the picture that are missing, or to probe more deeply in areas where the existing information base is judged to be inadequate.

Once the nutrition problem is mapped in this fashion, the analyst is provided with a coordinate system for fitting other information concerning causal factors and resource uses into his analytical framework.

2. Analysis of the causes of malnutrition. The mapping technique can be used to summarize a wide variety of information related to the nutrition problem. Data on family income, food production and consumption, marketing of food products, prices,

existence of potable water, environmental sanitation, health problems and services, etc., can be superimposed to provide spatial information concerning the determinants of malnutrition. As these basic data become available, statistical techniques such as discriminant analysis or factor analysis can be used to determine those factors which explain the largest amount of the variation in levels of malnutrition from area to area. It is in this way that gradually a picture of the relative importance of different causal factors will emerge.

3. Analysis of alternative interventions. As the data base concerning nutritional status and its determinant factors is built up, data concerning the provision of services destined to improve the nutritional situation will also be added to the data base. Evaluation of the impacts of different types of program activity in different areas will help to determine those program elements which have the greatest impact on the problem of malnutrition.

II. HEALTH

In our earlier discussion of the nutrition problem, and of the overall requirements for nutrition analysis and planning we indicated that the issues most closely related to health sector planning were those which concerned the biological utilization of nutrients. Inefficient use of nutrients stems in part from the quality of the diet itself, but a more important set of determinant factors, from the point of view of utilizing health sector analysis, consists of those surrounding the occurrence of infection in the individual.

Infection and Nutritional Status. Much research has gone into sorting out the relationships between infectious illness and malnutrition. It has been demonstrated that there exists a synergistic relationship, in the sense that the presence of either one tends to increase the likelihood that the other condition will appear or worsen. Infection depresses the appetite and causes losses of essential nutrients, while the existence of malnutrition reduces the body's ability to withstand the onslaught of disease agents. Most of the research work in this area has centered around the problem in young children, since it is this group which is most vulnerable to problems of malnutrition.

The presence of infection in the young child among certain economic strata in developing countries seems to be almost a continuous occurrence. In a study made in Guatemala, one child was observed to have had the following infections in his first 36 months: 3 cases of bronchitis; ten upper respiratory

infections; a bout with bronchopneumonia; 20 separate cases of diarrheal disease; measles; conjunctivitis; and several other illnesses; bringing the total to over 40 occurrences [16, 1975]. This averages out to more than one occurrence per month during the child's lifetime. Far from having been a worst case, that this child was in fact representative of the children in his village, in terms of both the frequency of occurrence and the kinds of infection experienced. Similar results have been shown to be the case all over the developing world.

Enteritis and other diarrheal diseases are either the primary causes or contributing factors in the majority of infant deaths in most developing countries. In Nicaragua, one study found that 23.6 per cent of all deaths were diagnosed as having been caused by these diseases. More than 90 per cent of these were children under 5 years of age [2, 1976]. In the Dominican Republic, roughly half of the infants hospitalized are interned because of gastroenteritis or other diarrheal disease. In the 1-4 year age group, 16 per cent are hospitalized for the same reason, while another 16 per cent who are hospitalized are suffering from malnutrition. It is probable that this latter group has suffered high incidence of diarrheal disease as well.

In addition to diarrheas, upper respiratory infections and communicable childhood diseases also contribute greatly to malnutrition. Otherwise nutritionally healthy children have been observed to develop moderate to severe protein-calorie malnutrition rapidly after the onset of infections such as measles,

diarrheal disease, whooping cough, or tuberculosis. A survey carried out in a rural village in Nicaragua in 1975 by investigators of the Ministry of Public Health found that 25 children under the age of 5 had died of measles within the previous year. This probably represents about one fourth of the entire population of children under 5 for the village.

For the purposes of determining how best to use health sector analysis as a vehicle for addressing nutritional concerns, it is important to analyze the socio-economic determinants of malnutrition, and not simply be satisfied with having observed and documented the immediate or proximate cause. In the case of childhood infections, there are several factors which are of overriding importance. These include water supply, disposition of waste materials, housing conditions, and exposure to communicable diseases.

Water Supply. Water supply is an important factor in three ways. Many infections which cause diarrheas in young children are the result of water borne bacteria, notable among them enteropathogenic *E. Coli*. Others are caused by bacteria such as *Shigella*, which are transmitted directly through the handling of materials contaminated with fecal matter or other animal matter. Thus while in some cases the water supply itself causes the infection, in the case of the *Shigella* agent water supply is not a causative factor. Studies have shown *Shigella* infections to be reduced considerably in cases where increased water supply led to improved personal hygiene. The third consideration concerning water supply is the tendency for small

children to dehydrate during episodes of diarrheal disease. It has been observed that children with diarrhea are better off drinking even contaminated water than reducing their water intake to the point where dehydration sets in.

In many parts of the developing world the poor obtain their drinking water only through great effort. Studies have shown that in many countries obtaining water occupies a considerable portion of the time of the family. The sources of this water vary. The family which has access to a deep well, even at some distance from the family dwelling, is much less likely to provision itself with contaminated water than is the family which must make do with water which comes from a surface supply such as a drainage ditch or steam polluted by waste matter.

A much needed element in health sector analysis is attention to the kinds of water supplies which can be constructed to provide low income families with a plentiful supply of potable water. Cost is of primary importance in designing water supply. In most developing countries the majority of the population lives in rural areas. The cost per person of delivering water via traditionally engineered aqueducts can be prohibitive. Alternatives exist. In many areas low cost shallow wells can be drilled, punched or dug, which will provide a safe and adequate supply of water. In other instances it is possible to construct small holding tanks which will catch spring water or rain water. Unit costs vary considerably, depending upon the dispersion of the population, the topography of the terrain, the existence and

and depth of subsurface water, etc. Experience with different kinds of systems in Central America during the past several years shows that the per person delivery cost can vary from as low as three to as high as one hundred dollars. The meaning of this cost difference strikes home when we state the cost data in a slightly different way. With a budget of 5 million dollars available for investment in water supply, a population of only fifty thousand persons could be reached at the higher cost figure, whereas at the lower figure over 1.5 million could be served.

Environmental Sanitation. The existence of poor housing conditions and unsanitary elimination of wastes, including human fecal matter, creates situations where the likelihood of infections is high. Dirt floors provide young children with opportunities to come in contact with disease agents such as parasites and enteropathogenic bacteria. Leaky and drafty dwellings increase the likelihood that respiratory infections will occur more frequently and be of longer duration. In the absence of latrines or other means of disposal of human wastes, the probability of diarrheal disease caused by *Shigella* is increased.

Studies carried out in Nicaragua as part of a recent health sector assessment showed the incidence of diarrhea in children under two years of age to correlate highly with poor housing and sanitation conditions [2, 1976].

Interventions to improve these situations must be of several types. Latrines can be constructed at low cost if materials

and technical assistance are provided. Housing conditions can be improved in a similar fashion. But experience has shown that before such projects can be successful the families involved must understand the reason for the improved sanitation measures, and must be willing to make the behavioral changes necessary for improvements to take place. In many instances this will necessitate efforts in health and nutrition education prior to or concurrent with project implementation.

Health and Nutrition Education. Although there is great potential for the use of education as a means of improving nutritional status, past efforts have been directed largely at the training of nutrition and health professionals, rather than raising the understanding of the public at large. Efforts are currently under way in several countries to explore the practicability of using mass media as a tool for producing behavioral changes designed to improve nutritional status.

In Nicaragua and the Philippines experimental spot messages on radio are being used to inform the public of specific items related to good nutrition. Examples include how to treat diarrhea in young children with home prepared rehydration salts, and why iodized salt is preferable to plain salt in areas where goiter is a problem. The preliminary results of surveys to evaluate the efficacy of these messages is encouraging.

Other approaches stress the inclusion of health and nutrition material in non-formal education aimed at adults and taught through radio, and the training of midwives in health and nutrition through short courses.

Preventive Health Care. Looking at the health sector from the point of view of nutrition, one discovers that most of the important activities fall into the category of preventive health services. Little can be done to address the problem of malnutrition in an effective way through curative health services. The delivery of preventive health services differs markedly from that of curative services. The latter can be thought of as a system driven largely by demand. Such is not the case with the planning of preventive health services. A further complication is that the services must be delivered "door-to-door".

A number of innovative approaches to the delivery of health services, along with water supply, environmental sanitation, and health and nutrition education, have been taken over the past few years. In Costa Rica a comprehensive program of nutrition-oriented services is being implemented, centered around rural health posts. A unique feature is that the paraprofessional health workers who man the posts ride circuit on the 200 or so families in their jurisdiction, visiting each household once every two months. This presents the opportunity for the health worker to have first hand knowledge of the factors influencing nutritional status. It also assures the delivery of curative and preventive health care and health/nutrition education, to every family within the sphere of action of the rural health post.

A similar program to the one above is in its pilot test stage in Colombia, with initial tests being carried out in the Cauca Valley. In the Colombia program, health promoters working out of health clinics cover a specified number of families in much the

same manner as do the health post workers in Costa Rica. The promoters give immunizations and vaccinations, provide health and nutrition education, and counsel families concerning the provision of sanitation measures. The Colombia program includes one feature not found in Costa Rica -- a food stamp component. Health promoters provide the mother of each child under two years of age with coupons which can be redeemed for food stamps at the local health clinic. The mother brings the child to the clinic (a necessary condition to receiving the food stamps), and the nurse at the clinic examines the child, taking height and weight measurement, and if necessary, programming a visit with the attendant physician.

Health Sector Analysis. There are several methodological approaches to health sector analysis and planning which are in relatively common use in the developing world. The principal ones of these have been developed by AID, the World Health Organization, the Pan American Sanitary Bureau, and the Pan American Health Organization. The latter three approaches are quite similar. They are geared to centralized planning of health resources. The procedures and kinds of anlaysis entered into one standardized, and oriented rather heavily toward curative health services. The AID approach to health sector analysis is not without a relatively heavy emphasis upon curative health services, but is much more loosely formulated procedurally than the other three approaches. It thus has a better chance, at least theoretically, to be used in a problem-oriented fashion to address problems such as nutrition. Indeed, the AID approach to health sector analysis is the only one which gives more than just passing mention to nutrition problems.

Beginning in 1974 AID began to cover nutrition problems in relatively great depth, giving them separate treatment in the health sector assessments which constitute the basic reporting method for sector analysis results. The latest innovation begun in the AID approach is to follow health sector assessment work with a full scale nutrition assessment if nutrition problems are shown to be substantial, and if host government interest is present.

Below we give short accounts of the methodologies used in these approaches to health sector analysis and planning.

AID health sector analysis. AID's approach to sector analysis has as its primary purpose to make available significant new information for sector decisions. The AID health sector assessment is geared both to national objectives and to host country institutional planning capabilities. AID considers health sector analysis activities to be part of a comprehensive health planning process, and analysis activities are selected on the basis of current and prior host country involvement with analysis and planning.

AID has outlined procedures for implementation of health sector analysis activities [7, 1973]. The process begins with the preparation of a scope of work. This scope of work is usually prepared by a team of professionals who travel to the country. During the scope of work preparation, an analysis of the country's technical and analytical capabilities will be carried out, and the magnitude and comprehensiveness of the study will be determined.

The objectives of the AID health assessment activity are:

1. Identification of feasible programs that can improve

sector performance, through a better understanding of alternative costs and impacts.

2. Estimation of production functions regarding levels of outputs in response to program inputs.

3. Identification of administrative bottlenecks to programs implementation.

4. Improvement of institutional health planning by providing a "learning by doing" experience.

5. Provision of a more factual basis for AID and other investment and for evaluation of past investments.

1. Identification of Problem Areas.

a. Description of Health Status. Most of the information required will be based on available data. Minimum information includes disease-specific mortality and morbidity rates, divided into communicable and noncommunicable disease categories. Additional surveys may be recommended. It is this first step which will help to evaluate what data items are missing and which items will be needed for further analysis.

b. Examination of Ecological/environmental Influences on Health. Data include the geography of the country, transportation networks, communications, climate, seasons, economic situation, food availability, etc.

c. Population Characteristics. Minimum information includes age structure of population, distribution, birth rates, fertility rates, mortality rates, population projections, educational levels, social characteristics disaggregated when possible by socio-economic levels.

d. Description of Health Care Delivery System. Services, broken down into facilities and manpower, are identified and their distribution is examined. Problems within the delivery system, i.e., inefficiencies, maldistribution, poor utilization.

e. Economic Effects of Health Status. Direct costs and indirect cost of health problems. Direct costs refer to the costs of curative and preventive measures addressed to a particular problem. Indirect costs include lost productivity from illness or premature death, absenteeism from school, effects on other development projects, etc.

f. Intersectoral Relationships that Relate to Health Problems.

g. The Political and Administrative Structure of the Country.

2. Select Analytical Studies to Address Specific Problem Areas.

a. Each problem chosen as an area of more detailed study will be analyzed with the following items in mind:

(1) Each problem area will be treated as a subsystem of the health sector. Those activities within the health sector that affect that problem will be identified and evaluated along with those activities outside the health sector that influence the problem.

(2) Activities and/or programs existing that address the problem will be broken down by physical resources used and the monetary costs of these resources. Efficiencies of current programs will be investigated. Costs per unit output will be estimated.

(3) Recommendations then will be made regarding how to improve efficiencies of current resources addressing a particular problem, and how additional resources should be allocated.

(4) Recommendations regarding innovative program design, further studies, etc.

b. Problem areas that have been identified as most critical include nutrition, environmental sanitation, maternal and child health, communicable diseases, health services, population size and growth rate, administrative capacities, and education and agriculture as they relate to health and nutrition.

Typical information and information required for three of the above problem areas include the following:

(1) Nutrition. Identification of the nutrition system and relevant components; analysis of food production and importation, transportation, processing and storage, distribution, food preparation, consumption habits, etc. Analytical activities may involve analysis of nutrition surveys for determination of nutrition status of population, modification of agricultural sector models to reflect nutrient availability, development of strategies to eliminate problems within any of these subsystems that have negative effects on nutrition status.

(2) Population Studies. Evaluation and analysis of available demographic data, description and evaluation of

current population planning programs, evaluation of effects of health programs on population programs, and vice versa, identify alternative strategies for achievement of family pla ning targets.

(3) Health Service. Description and evaluation of current health services; identification of resources available for delivery of services; analysis of population demand and attitudes towards health services; study of costs and impacts of alternative types of health delivery systems; identification of marginal returns to alternative technologies (various combinations of levels of manpower, equipment); study of health sector financing, identification of alternative sources of financing, price elasticities of supply and effects of various payment mechanisms on demand; study of health sector administration.

3. Application of Studies to Assist in Country Allocation of Resources and AID Investments.

a. Priority problem areas are identified and the multiple factors that influence the problem are examined. Models of subsystems are now being developed and aid in understanding relationships of those variables involved in problem causation and those factors which obstruct current program effectiveness. This might prevent resources from being wasted on programs that will have virtually no impact because they only address one or two of the factors causing the problem.

b. Cost-effectiveness studies aid in guiding resource investment in those projects which have the largest returns per resource invested.

c. Initial activities point to additional analytical studies that should be undertaken to improve and/or expand present information needed for better decisions.

The AID approach to health sector analysis sometimes suffers from the timing constraints imposed by the annual budget cycle. In some instances this results in less than an ideal amount of time for completion of sector analysis activities. A feature of the AID approach which somewhat offsets this is that analytical activities are often included in grant and loan projects for implementation during the life of the program of AID assistance.

PAHO CENDES Methodology. The CENDES methodology has provided the basis for a number of health sector planning activities. Over 3,000 Latin Americans have been trained in its use and application. The approach was developed in the early 1960's by the Pan American Health Organization and the Center for Development Studies at the Central University of Venezuela. It is characterized by its use of disaggregate data, its emphasis on planning from the bottom up, and its implicit structured procedures and applied quantitative techniques. Its objectives are:

1. To provide concepts and analytical techniques that will aid in the systematic and rational allocation of resources in the health sector.

2. To identify data that should be collected routinely in order that analysis be a viable instrument of decision making.

3. Specifically, to provide information that will:

   a. Reveal inefficiencies in the existing allocation of health resources.

   b. Identify the optimal combination of resources and techniques which will show the largest outputs compared to the inputs.

   c. Determine the level of expenditure and bill of physical inputs needed in order to maintain the existing level of health care for a period of about 10 years.

Procedures. A six-step procedure consisting of diagnosis, prognosis, evaluation, calculation of a maximal plan, and the preparation of national and regional feasible plans, is used.

Diagnosis. The purpose of this first part of the methodology is to define the target population, using disaggregate regional data, collect data required to describe the prevailing health situation, and to evaluate health problems. Steps are:

1. Determine local and regional planning areas based on

population size, availability of permanent health resources and administrative infrastructure.

2. Determine priority of disease problems for planning purposes, by collecting data on morbidity and mortality from national statistics, hospital records, and outpatient sources.

3. Describe existing health programs and their components. Operating and capital costs are calculated for each program, as are physical inputs in terms of manpower, facilities, and equipment.

4. Determine allocation of resources aimed at particular diseases. Organize data so that efficiency with which resources have been used to combat disease may be evaluated.

5. Determine efficiency of instruments used for each disease:

a. Identify and count the number of instruments used for each disease.

b. Calculate the number of tasks involved, their concentration and coverage. Establish norms, standards based on investigation and expert judgement regarding appropriate intensity and coverage.

c. Calculate costs to combat each disease. Costs are calculated by instrument, with human resources and other costs broken down by instrument. Costs per person are then calculated.

d. Calculate effectiveness and unit cost for curative services, and unit costs of preventive services, by disease.

e. Examine methods in use for effectiveness. Analysis is directed to whether instruments are adequate with respect to: (1) concentration; (2) coverage; (3) composition; and (4) effectiveness.

6. Recommendations for correcting inefficiencies.

a. Operational standards and norms are established by judging from data and expert opinions.

b. Costs of inefficiencies are estimated.

c. Calculation of benefits from reallocation of reresources are calculated. This is normally in terms of the number of deaths averted.

7. Development of feasible alternatives by local planning areas bsded on the information provided in the preceding steps. A minimum plan is prepared with the same budget level as was experienced in the previous year.

8. Information are obtained on population and other factors contributing to health problems. These factors include: population characteristics; disease agents; physical environment; socio-cultural factors; and economic, political and administrative factors which affect health policies and programs.

Prognosis of health situation. The purpose of this set of activities is to determine the likely pattern of health conditions over the ensuing 10 years if there is no change in health policy. Steps are:

1. Projection of population by age group.

2. Projection of death rates, by disease, according to current trends. Corrections are made for health facilities currently under construction, along with assumed changes in income, literacy, nutritional levels, and other factors.

Evaluation of the health situation. This step is intended to determine whether it would have been possible to reach a higher level of health status in the past with a different allocation of resources. Elements are:

1. Examination of the distribution of resources among reducible diseases.

2. Examination of high-cost diseases and development of strategies for lowering costs.

3. Calculation of costs required to meet the demand for non-reducible disease services, in order to maintain existing mortality rates.

Calculation of maximal plan. This step calculates the resources required to increase the health level of the community to the highest level possible.

Preparation of Regional Plans. The preparation of regional plans involves the following elements:

1. Coordination of local plans.

2. Incorporation of special services that can be most efficiently operated at a regional level.

3. Estimation of total costs for all local plan expen-

ditures to maintain health levels of the preceding year.

4. Set priorities for allocation of resources in the region, according to specific programs.

Preparation of a national plan. Steps are:

1. Coordination of regional plans.

2. Distribution of additional resources over the previous year's budget among the regions in such a way that maximum reduction in the number of deaths is assured, together with minimum cost per case treated.

System of Quadrennial Projections. In the early 1960's the Charter of Punta del Este produced commitments by Latin American governments to integrate social and sector planning with national development plans. The need to harmonize the external assistance programs with ongoing programs was recognized. In 1967 the Director of the Pan American Sanitary Bureau called for the development of a system that would make it possible to plan the Organization's assistance to countries over a four year period, with the objective of increasing efficiency in the medium term programming of its activities. The outstanding characteristic of the resulting system is that it is possible to use different analytical techniques in different ones of its components. The system is intended to offer flexibility in its application, and to have a usefulness that can grow with the growing analytical capabilities of a country.

The objectives of the system of quadrennial projections are:

1. To ensure that external assistance will be instrumental in supporting priority programs of the health sector.

2. To facilitate coordiantion of external assistance in the field of health with other economic and social development programs.

3. To establish the basis of an extremely simple and flexible planning methodology for national health programming.

4. To permit the use of more exact and efficient analytical techniques as a country improves its analytical capabilities.

5. To accelerate the planning process and to facilitate communication between different levels of sectoral and institutional administration, as well as intersectoral coordination.

There are four sets of procedural steps whcih make up the system of quadrennial projections.

Identification and compilation of basic data. Data are selected and systematized in accordance with availability, and are grouped in categories for purposes of uniformity and comparability at the hemispheric level. A format for presentation of the data and projections has been specified in a fashion that will expedite further analysis. Past data is used in order to establish trends.

1. Identification of components includes: a general description of the country, including geographic and topographic considerations, climate, transportation system, political structure, language, habits and customs, etc.; demographic characteristics, including population projections by age groups, mortality and fertility rates; economic, social and environmental characteristics, including per capita GNP by sectors of production, literacy of the population, water systems, per capita calorie and protein consumption, housing, and a listing of the country's overall development programs.

2. Collection of information includes data concerning: mortality by age group and cause; morbidity by age group; disease incidence and prevalence; nutrition problems as indicated by grades of malnutrition in children under 5; mortality rates for children 1-5; prevalence of goiter; health resources, categories and gepgraphic distribution of human resources.

Sectoral Situation, Health Policies, and National Strategies.

1. Definition of health goals and objectives. National development goals are specified along with those objectives set forth in the Ten Year Health Plan of the Americas. Goals are specified concerning the reduction in mortality and increase in life expectancy at birth. Objectives are specified in terms of coverage of various levels of services to reach the stated goals. Objectives are quantified.

2. Summary of present health situation in terms of past goals and objectives.

a. Current programs are reviewed to see if resource utilization is adequate and if stated objectives are being met.

b. Factors constraining programs are identified. Resource, manpower, management, financial, and administrative constraints are reviewed.

c. Additional objectives aimed at overcoming the identified constraints are set.

d. Strategies for reaching these new objectives are determined and new program areas identified.

National Health Programming by Priorities.

1. Programs are identified in accordance with objectives and strategies determined in previous steps. Resource components of these programs, populations to be covered are determined.

2. Costs, physical inputs and operating and capital budgets are calculated for each program.

3. Expected change in coverage by health level is recorded.

4. Change in investment and operating costs during the programming period are calculated by region and for the country.

5. Estimates of resource needs by resource category are calculated.

6. Current expenditures and capital expenditures by government organization, private agency, external donor are listed by program. Past expenditures as well as projections of future expenditures are made.

7. Trends for health sector expenditures and overall public investment and operating budgets are projected.

Analysis of External Assistance. This part of the analysis includes a summary of international assistance by program, broken down into types of resources offered: human; technological; administrative infrastructure; biological research; and contributions to complementary services.

The programming subsystem is divided into formulation of

medium term programs, typically using a four year horizon, and short term programming, with a one year horizon. Data requirements are directed to information needed for evaluation of programs at the national level.

Medium term programming has three basic objectives: (1) improvement of medium term national programming, which is regarded as a fundamental instrument for the implementation of national health policies; (2) development of country planning processes, sectoral and intersectoral; and (3) improvement of the programming of the joint Country-PAHO activities through a better systematization of programs, objectives, and activities. Procedures include:

1. Analysis of selected health problems and estimation of of the anticipated impact of each program addressed to that problem.

   a. Identification of the problem in terms of its effects on population groups.

   b. Identify those programs directed toward the problem in terms of financial constraints, supplementary services, and national sectoral and institutional infrastructure.

   c. Outline the present situation in terms of objectives that have been designated.

   d. Indicate the impact of the problem on health status, and on other development programs. Estimate the impact of the problem over the next few years if no action is taken.

2. Scope of work for each of the four years of medium term programming.

   a. Objectives of all programs are defined on an annual basis.

   b. Components and major activities are identified for each program.

   c. Geographic coverage, percentage of population affected, by age, sex, and socio-economic group is estimated.

   d. Responsibilities for implementation are identified.

e. Individual objectives of each activity and component are stated and quantified.

f. Indicators that will measure the degree of attainment of programs and subprograms are specified.

g. Activities for reaching objectives are scheduled.

h. Resources required for each year are calculated, as are the expected outputs.

i. Programs are analyzed for relative costs and effectiveness.

WHO Country Health Programming. Country health programming, sponsored by the World Health Organization, is described as a continuing process leading to improvement in planning, programming, implementation and evaluation of health services and programs. Essentially, Country Health Programming is a program budgeting process whereby country programs are developed to meet stated objectives and budgets are prepared with respect to programs. Emphasis is placed on the interactions between the health sector and other sectors. Guiding principles have been: (1) quantification of baseline and target levels of health status; (2) quantification of both inputs and outputs of activities directed to improving the health status of the population; (3) conducting input/output studies where data is needed; (4) determination of the most efficient ways of reaching objectives; and (5) developing numerous approaches for the study of feasibility.

A major goal of country health programming is to provide information so that governments can direct external assistance to priority programs. The analytical activities, specified by WHO, are directed to; (1) selecting priority problems; (2) specifying operational objectives within a country's planning cycle; (3) translating these objectives into health programs with regard to resource constraints; (4) identification of realistic

resource needs; (5) comparing courses of action as to costs of inputs and levels of outputs; and (6) developing viable strategies and programs for implementation. The programming process is headed by an ad hoc group of health sector professionals. The procedure contains seven steps:

1. Data Collection, Analysis, Presentation

The data collected and analyzed include both intersectoral and extrasectoral components and activities that effect health status. Available data are used.

a. Health Status Determination. The minimum requirements at this stage include one table with mortality rates by age, sex and region (if possible) for a recent time period, by disease class, and another table showing morbidity rates, sources of data, and comparisons of disease rates by specific population groups.

b. Demographic Data Forecasts. Minimum information requirements specify rural/urban population distribution, age structure of the population, birth rates, fertility rates, crude death rates, and other vital statistics.

c. Description of Health and Environmental Health Services. Tables are required showing distribution of health facilities and manpower resources by region. Table indicating the location of health services and environmental services are constructed, showing population coverage and utilization rates.

d. Economic Data. Forecasts of gross domestic product and/or gross national product. Calculations include estimates of general revenue growth and public expenditures.

e. Unit Cost Data. Service programs are broken down into tabular form showing cost per unit of output or activity; i.e., cost per vaccination, cost per hospital bed per day. The unit cost data are broken down into component costs: operating costs, salaries, capital costs, transportation costs, etc.

f. Policy Data. Information is provided concerning both national development policies, goals and objectives, and health policies, goals and objectives.

g. Other Data. As the analysis proceeds, other information that is needed for particular studies will be specified.

Data collection is recognized as an ongoing activity throughout the programming procedure. Other areas of study requiring information include the political system and administrative framework of the government, the managerial and planning capabilities of the country, etc.

2. Information Analysis

After collection of basic data is completed, a document is put together to serve as a basis of knowledge for the team that will be setting objectives, determining strategies and developing programs. The data collected may also serve as a country health profile document to be used for internal government purposes. Of particular importance is a detailed analysis of the probable impact of the health situation on economic and social development and the impact of socio-economic trends on the health situation.

3. Situational Analysis and Preparation of Program Proposal

a. Identification of Health Concerns and Problem Areas. This is disease-oriented, and activities include the listing of disease-related problems followed by shortcomings in the provision of services and the availability and distribution of manpower dire ted at these particular problems. Environmental health problems are included as well as extrasectoral problems caused or exacerbated by health problems.

b. Selection of Priority Problems. (1) Members of the *ad hoc* committee make a preliminary list of health problems and rank them in order of importance from their own perspective; (2) New lists are prepared by each member based on the information document and further discussion; (3) Priorities are then determined by integrating the subjective listings with collected data indicating mortality and morbidity rates by disease. A rank is given to each disease based on its intensity, fatality indicated from the data, etc. and is combined with rankings subjectively given to each problem; and (4) Problems are further broken down and refined and priorities listed in terms of lack of supporting services, inefficiencies of existing services, and lack of information, etc.

c. Identification of Current Programs and Activities Addressed to Problem Priority Areas. All resources and activities, both in the health sector and outside the health

sector, that are currently directed to each problem area are identified.

d. Identification of Resources Utilized by Activities Addressed to Problem Priority Areas. Both physical resources, in terms of facilities, manpower, equipment, and monetary resources are estimated for all activities. Output by activity is determined.

e. Assessment of the Efficiency With Which Each Problem is Being Met. Activities are broken down into costs and outputs by individual component; e.g., manhours utilized per vaccination, drugs used per operation. Further analysis is to address the extent to which ongoing activities are meeting problems and how efficiently this is being done.

f. Identification of Problem/Output Indicators. This step includes the selection of indicators which will be used to measure change in health status.

g. Objective Setting. The *ad hoc* group reviews targets set for particular problems by existing national health plans, etc. New objectives are set and defined in terms of problem/output indicators.

4. Health Strategy Development and Feasibility.

a. Alternative Strategies. For each priority health concern and corresponding contributory factors, a list of strategies is drawn up. A strategy is defined as a group of inter-related public health techniques organized to achieve a stated objective. Alternative strategies for reaching the same objectives are proposed. For each strategy the technical approach and methods of application are described.

b. Feasibility Analysis. At this point the feasibility analysis of strategies includes an evaluation of political, cultural, social, administrative constraints. Analysis includes recommendations for overcoming constraints if it seems possible, strategies and time frames.

5. Determination of Health Development Programs.

a. Those strategies which are free from constraints as studied in the preceding steps are translated into specific programs. For each program, the resource requirements in terms of physical inputs and costs are determined. Population coverage, as far as age groups, geographic coverage, socioeconomic categories are specified. Time frames for implementation of programs are estimated, and the corresponding administrative, communication infrastructures

necessary are identified. Alternative ways of implementing programs are specified as well as alternative combinations of staff. Costs are broken down into capital, recurring, equipment, logistics support, information services, etc.

6. Constraint Analysis of Health Development Program.

a. Analysis of Support Requirements. Encompasses determination of probability of resources (manpower, supplies, equipment and construction) being available at the right time and place for development and implementation of programs.

b. Overcoming Constraints. Alternative solutions to overcoming constraints are proposed, making use of existing resources and application of new but readily available technology.

c. Financial Analysis. Includes calculating and comparing the costs and effectiveness of programs, determining if there are more efficient ways of achieving objectives, and identifying probable levels and sources of funds.

7. Social and Economic Repercussions.

a. Each development program is examined regarding its overall effect on national development.

b. Cost-benefit analysis is applied to compare investments in health projects with investments in other sectors.

This concludes the descriptive material concerning various approaches to sector analysis in health.

Addressing Nutrition through Health Sector Analysis. In the first chapter we indicated that the four areas of analysis related to nutrition planning are: (1) analysis of the extent and severity of malnutrition; (2) analysis of the causes of malnutrition; (3) analysis of alternative interventions for combatting malnutrition; and (4) analysis of overall resource allocation priorities.

Data concerning the extent and severity of malnutrition are commonly produced within the health sector. Means for rapid and inexpensive generation of data on nutritional status of young children have been improved in the past few years with the introduction of plastic arm bands for measuring arm circum-

ference. The results of using this quicker and less costly technique have been shown to correlate reasonably well with the more standard approach of using weight for age measurements.

In terms of our conceptual framework for analyzing the nutrition problem (Figure 1., page 6) measurement of changes in nutritional status can be taken as the dependent variable in the development of statistical models, such as path models, for determining the relative importance of various determinant factors. Several different statistical approaches warrant utilization for the development of such models, among them factor analysis, discriminant analysis, and path analysis, in addition to the standard regression models already in use to some extent. These models can be developed at the macro level as represented in our conceptual planning framework, or can be developed to represent some specific set of relationships felt to be important. In the first instance, a model relating the existence of potable water and/or latrines for sanitary waste disposal to level of nutritional status in a geographic area might be constructed. In the second, a model of the factors influencing nutritional status in pregnant women, or a similar model for nursing mothers, might be developed.

In general it is this kind of analytical effort which takes us beyond the descriptive level to the level of structure. An understanding of this structure is basic to being able to design effective methods for combatting malnutrition. It is the model which allows us to estimate the likely effects of program interventions upon the nutritional status that we hope ultimately to be able to improve.

Probing farther down into the problem, models at the policy level are important in order that resource allocation decisions be well understood. Few studies of this kind exist in the health sector (See [10, 1973], [2, 1972], [5,1970], and [2, 1967].) Most of the existing models have been constructed to enable one to analyze specific methods of intervention, or specific disease systems. Practically no work has gone into developing sector models; that is, models which embody relationships at the sector level. Before resource allocation models of this type can be developed, there are two prerequisite steps: (1) causal models at the sector level must exist and be well understood; and (2) the alternatives for investment aimed at reducing malnutrition, as a function of these causal relationships, must be understood. Both of these types of analysis are in their infancy in the health sector. And both are of primary importance for future health sector analysis activities.

Evaluation activities built into existing program or pilot project activity are important sources of information leading to an understanding of the costs and benefits of alternative program interventions. The use of evaluation as a method of analysis is one of the more important methodological tools at the disposal of the analyst.

The richer the data base for analysis, the more difficult it is to use the data base well, and the more costly it is to acquire it, store it, and use it. Numerical and descriptive information have a way of confounding easy analysis in their original forms, when the amount of information passes a certain limit. The importance of methods for summarizing information in ways that facilitate its understanding are very important to

successful analysis. Models serve this purpose, of course, by deriving general statements relating one or more aspects of a problem from large quantities of data. In the study of the relationships between health and nutritional status, the use of mapping techniques is an important way to enhance the understandability of information. By displaying information on a map of a rural area, for instance, it is possible to form a comprehensive model of the relationships involved in the determination of nutritional status. Information concerning water supply and environmental sanitation can be displayed easily, as can the coverage (on a house-by-house basis, if desirable) of medical and other health and nutrition services offered in the area. This use of mapping techniques to summarize information in a structured form, should be integrated into health sector analysis activities whenever possible.

Another goal of sector analysis should be the determination of indicators of nutritional well being or nutritional risk, which can be used to focus attention on particular groups of the population for planning purposes. The use of anthropometric measures of nutritional status in young children is an excellent example of an indicator. The mapping of malnutrition and factors related to it is one way to explore the development of such indicators.

The approach suggested here is a problem-oriented one. It stresses the use of a conceptual planning framework embodying the principal determinants of malnutrition related to health sector concerns. The main objective of health sector analysis, departing from this conceptual framework, is to develop the specific information necessary to understand the exact way

the various determinant factors -- water supply, environmental sanitation, and the frequency and duration of illness, interact to impact nutritional status, and, knowing these relationships, analyze the alternatives available for acting to combat malnutrition with respect to their costs and benefits.

III. AGRICULTURE

The Purpose of Agriculture Sector Analysis. What is the purpose of agriculture sector analysis? We quote the following:

> "The fundamental purpose of (agriculture) sector analysis is to devise agricultural and rural sector programmes that achieve increases in food production while substantially reducing ... problems of underemployment, unequal income distribution and low levels of living for the poor majorities of (LDC) populations. It deals with the complicated effects on these key goals of policy choices that involve complex interactions of a large number of important variables. It involves interrelated farm and non-farm socio-economic systems that must change radically and rapidly but that are not well understood. It evaluates alternatives for policymakers where inadequate analysis can be costly in terms of waste of scarce resources or unintended and unanticipated consequences for their priority goals and target populations."[1/]

The goals referred to above, and development goals in general, have a pervasive influence on how we constitute sector analysis. In the first place we want to know what impacts proposed programs and policies are likely to have on these goals. Thus our sector analysis methods must allow us to estimate these impacts before the fact, and hence the methods themselves will be determined or at least conditioned by the goals we choose.

Another significant factor has to do with the character of the agriculture sector itself. The agriculture sector is an example of what systems theorists call a self-organizing system. Such a system in its abstract form, has an environment in which it functions; a currency, or energy, which is available from the environment, and which is conserved on the average; and a

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[1/] Lehman B. Fletcher, ibid.

set of system components which act as servomechanisms and are currency seeking. The only way in which one of these components can increase the currency it has available is by influencing the activity of other components. Such attempts bring about networks of interrelated activity, or system organization, which govern the behavior of the total system. It should be clear that measures of total system behavior will be related to, but not necessary identical with, individual component behavior.

This autonomous behavior of a self-organizing system creates complications when one wishes to control, or influence, the behavior of the system. It is for this reason that the 'systems approaches' of the past couple of decades or so have had limited success when applied to many social and economic systems. Such approaches have in large part been developed for the control of single-purpose systems, or systems which are centrally managed and controlled.

Methods for influencing the behavior of a self-organizing system in the direction of goals which are derived independently of the system and its own internal goals will be in general more complex than for single-purpose of centrally controlled systems. It may be necessary for the components in a self-organizing system to be induced through indirect means into behaving in ways determined externally to the system itself. This means that system behavior patterns and operation structure must be known to a far greater degree than in centrally-controlled systems; and the relationships between component behavior and

the performance of the entire system must also be well understood.

It is the goal of agriculture sector analysis to provide this understanding, and to be able to predict changes in sector behavior in terms of development goals, when the system under consideration is the agriculture sector.

The Agriculture Sector. While it is not necessary for the end purpose of this document to elaborate a precise definition of the agriculture sector, we wish to at least sketch such a definition in general terms. The agriculture sector is taken to encompass all activities which use land in a productive capacity. Thus food production activities, both involving plants and animals, are included. In addition we include such fiber products as jute and forest products. It is also sometimes the case that hunting and fishing activities are included in the agriculture sector. Lastly, since producers on the land must sustain themselves, the sector includes their consumption activities as well.

For the purposes of analysis it is necessary to distinguish two principal subsectors of the agriculture sector. The first of these we shall label the commercial subsector. This consists of those activities whose primary purpose, from the point of view of the producer, is to generate a cash income. Research has shown that for practical purposes it may be assumed that the objective function of producers in this sector is to maximize profits.

In addition to activities whose primary purpose is for the generation of a cash income, the agriculture sector contains

activities engated in for other purposes, as well. Although most small farms in developing countries cannot be considered in a microeconomic sense to lie outside of the cash economy, their primary concern is the production of food and fiber for the family's use. What cash incomes they earn (and they need some--if only to buy salt) are secondary considerations. Other farms are operated in a dualistic fashion, generating cash incomes for a variety of consumption goods and reinvestments from a portion of their activities, and containing as well a self-sufficiency component. Those activities engaged in for other commercial purposes we shall take to constitute the subsistence subsector.

Since our definitions above refer to activities rather than individuals, it is possible for a producer to be numbered in both subsectors. This is consistent with observed fact. There are indeed producers whose objectives for certain activities may be taken to be profit maximization, but whose objectives, and consequently whose production decisions, are quite different for other activities in which they engage.

This lack of mutual exclusivity between the two subsectors in terms of the individuals associated with them is not harmful as far as sector analysis is concerned, since eventual policies and programs will in most cases be defined in terms of the activities of the sector rather than in terms of the individuals who engage in them.

Many of the existing analytical tools have sufficient flexibility and adaptability to serve equally well for analysis of the commercial or the subsistence subsector. Orientation of

usage, model specification, and data requirements may differ widely, however. As we proceed we shall see that there is a need for careful study of both subsectors.

Agriculture Sector Analysis Methodology. The methodology for agriculture sector analysis must do a number of things. On the one hand it must address the multiple goals that developing countries consider important, among them food production, income distribution, employment. It must link together variables at the micro level concerning production, consumption, etc. and policy variables at the sector level. It must treat the complex interrelationships among the interconnected and overlapping social systems whose behavior impact upon development goals. And it must provide for the identification and specification of policy and program instruments for addressing these goals.

Because of the need for identification of problems at a high level of disaggregation, the information requirements for agriculture sector analysis are imposing. Information requirements as used here does not refer simply to the need for data, or information at the descriptive level, although that is indeed one of the more demanding needs. We refer in addition to the structural information which can only derive from the use of theoretical models.

In this section we shall give an overview of the kinds of models which are used in agriculture sector analysis, along with the data required for them, and the kinds of policy outputs which are obtainable from them. In the technical appendix which follows at the end of the section, we will treat these in more detail.

Sector Models. We shall define a sector model as one which encompasses all of the sources of supply within the sector, and contains linkages between that supply and aggregate demand. One of the characteristics of sector models is that they disaggregate activities within the sector to a much higher level than other types of global or semi-global models. In a model of the agriculture sector we may find that several producing regions of the country are represented. We may also find that producers are categorized according to the level of production technology that they use, by the size of their farms, or the quality or type of land used in production (soil type, altitude, etc.). Although many models represent the sector in operation during one year, there are also sector models which represent operations on a monthly or seasonal basis, and there are those which span several years of production.

Thorbecke[1/] classifies sector models into four categories by what he calls the conceptual framework of the models. These categories are (1) multi-level planning models; (2) microeconomic-dynamic models; (3) simulation-systems models; and (4) general equilibrium-consistency models.

The multi-level planning model includes activities which are aggregated within the model to several levels. In the Mexico-World Bank model of Mexico, for instance, there are district submodels and regional submodels, so that three planning levels are represented.

1/ Erik Thorbecke, "Sector Analysis and Models of Agriculture in Developing Countries," Stanford University Food Research Institute Study No. 1, 1973.

The microeconomic-dynamic model is constructed using microeconomic production data, and can be thought of as a farm model aggregated to a higher level. It is dynamic in that a number of production cycles are modelled, and the values of certain parameters for a given cycle are dependent on the model results for the previous cycle.

The simulation-systems model [1/] consists of a number of sectoral relationships cast in a consistency framework. That is to say, the model is so constructed to be consistent with a predetermined set of economic relationships as observed in the economy. Examples of such relationships include production, marketing and consumption activities for agricultural crops, which generate income, and demand functions based on income and population levels. The model is used in a simulation mode; that is, changes are made in certain variables, such as crop prices, public investment, import policies, etc., and the model estimates consequent changes in other sector variables. This allows for the analysis of impacts of different settings of policy and state variables upon such variables as farm and non-farm income, foreign exchange balances, and employment.

The category labelled as a general equilibrium-consistency framework fits the notion of a framework better than a model, because closed-form models are generally not used. Instead, a variety of methods are used in an iterative framework. For example, in one such approach projections of demand, gross output,

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1/ The simulation-systems model, also called a systems-simulation model, is defined in general more by the computational mechanism used by the specific analytical techniques. The model is cast into a computer program which allows 'simulation runs' to be made, altering values of parameters and exogenous variables and producing the consequent model outputs.

value added and employment are derived form a framework consisting of an aggregate macroeconomic model and an input-output model.

Thorbecke notes that models may be restricted to one period or they may cover a number of periods. In the latter case they are called dynamic. They may be constructed at the micro-level or at the macro-level, and may contain various forms of linkages (e.g. farm-region, farm-sector, district-region, region-sector, sector-economy). They may make use of several different methods and techniques: linear programming; recursive programming; recursive systems analysis; may incorporate different technological alternatives; and may contain activities such as labor migration at the regional or sectoral levels. The number of possible configurations of sector models is thus understandably quite large.

Below we discuss some of the sector models which have been constructed in various countries. For purposes of exposition we divide these into two categories, based on the techniques chosen for the models in question. These techniques, or procedures, may be called consistency and optimization.

Consistency procedure models. Consistency models have frequently been used to evaluate policy potentials at the macro-level. Such models have been constructed for Nigeria, South Korea, the Punjab, Peru, Guatemala, and Panama, among others. They are based on econometric analysis of time series data, and inter-sectoral input-output coefficients.

The most common application of consistency procedures in agriculture are the commodity supply and demand projections done periodically by governments and various international agencies.

These techniques have also been applied to the analysis of various policy issues. Generally national policy objectives concerning income, employment, output and balance of payments are linked to agricultural production through specification of agricultural commodity supply and demand relations, and/or input-output tables. Since agriculture, and in particular subsistence agriculture, has few backward linkages, input-output analysis is used to examine forward linkages and possible bottlenecks in processing and marketing functions. Commodity projections give an indication of probable growth in agriculture sector demand and supply, and in net agricultural trade. This type of analysis is usually possible in cases where micro data are noticeably sparse. It can predict the impact of supposed changes in agricultural production on the above-mentioned macro-economic variables, but cannot compare the relative impacts of various sector policy options on the composition and quantity of agricultural output.

Another consistency framework which has been used for agricultural sector analysis is the so-called computer systems simulation approach. Here relationships among relevant variables are estimated either through the use of econometric methods, or by the researchers' judgement, resulting in a set of equations capable of describing system operation, and reproducing the performance of certain key variables over time. Because of less stringent data requirements, simulation models may include substantially larger numbers of variables than econometric equilibrium models, including variables that are easily quantified or for which data are spare or non-existent. Once the system has simulated successfully, through adjustments in model parameters,

extrapolations can be made into the future the sensitivity of the system to policy options traced.

Undoubtedly the most ambitious agricultural simulations studies yet undertaken have been the studies done by Michigan State University for Nigeria and South Korea. The Nigeria model is made up of two regional submodels for the agriculture sector, and a national accounts model [6, 1971]. The system of 2,000 equations allows simulation of the effects of such policy parameters as export taxes, marketing controls and production campaigns, on a series of performance variables including value added foreign exchange, per capita income distribution, tax revenues and rates of investment. Regional specialization and interregional trade patterns are also generated for the regions included in the model.

A somewhat simpler example is the model constructed by Mellor and Mudahar to examine a modernizing agriculture sector in the Punjab, India [11, 1974]. Sensitivity of the 35 equation model to the following variables is assessed: twice taken to reach full employment in the economy; rate of growth of foodgrain production; sectoral employment growth rates; sectoral employment patterns; rates of growth in demand for non-foodgrains and agro-industrial products; and per capita income. The four key parameters for the model are: yield growth in the modern foodgrain subsector; yield growth in the traditional foodgrain sector; land transfer from traditional to modern usage; and population growth.

The consistency procedure approach has yet to be given much attention as a possible tool for micro-level models. An interesting application, and the only one we have discovered, is the model

of a village constructed by Arthur Dommen (See Appendix and [4, 1974]).

Optimization models. The basic technique underlying optimizing models is linear programming. The chief constraint in the formulation and implementation of linear programming models in the agricultural sector is the need for rather specific kinds of data. Data gaps are often filled by researcher judgements, but because of the normative nature of the solution procedure, inaccurate judgements tend to have more serious consequences for the model than in the case of the looser theoretical structure of the simulation model.

Optimization procedure models of one farm or another have been constructed for Mexico, Honduras, the Ivory Coast, Brazil, Portugal, Colombia, Egypt, South Vietnam, and the Punjab. Agricultural sector analyses which have used linear programming fall into these general groups: (1) micro-based, dynamic models aggregated to the regional or sectoral level; see reference [20, 1973]; (2) multi-level models with endogenous prices [12, 1973]; and income-based sector level models [22, 1974].

R. H. Day has been the predominant researcher and promoter of linear programming as a method for predicting supply response in agriculture. He has developed the method of recursive programming, which he uses in a positive, rather than a normative, fashion. The decisions predicted by the model are made one period at a time (myopic decision-making), but information is fed forward into future decisions (learning by doing). I. J. Singh has applied recursive decision models to agriculture sector analysis in developing countries. His model of Punjab agriculture included an annual objective function measuring

expected revenues from crop sales, costs of purchased and hired imputs, and investment charges; a technology matrix representing the input-output structure of home and cash consumption, farm production, investment, sales, etc.; land, labor, financial and consumption constraints; and exogenously given input and output prices. Dynamic applications which are possible include simulating economic history, impacts of policy alternatives, and crop projections.

One of the grandest designs of sector models is the CHAC model, produced jointly by the Mexican government and the World Bank. The model has been dealt with extensively in [12, 1973]. It consists of almost 2,500 equations covering a wide variety of agricultural activities, and has built-in demand functions, which allows prices to be produced endogenously.

Other Sector Studies, Models and Techniques. We have said that an important underlying theme of sector analysis is to link together production and consumption activities at the micro level with policy and program variables at the sector level, and to estimate the linkages, as well, between the agriculture sector and the rest of the economy. The sector models above manage to do these things to one degree or another, but in each case the intent to carry out these linkages, and to be able to estimate the impacts of alternative policy and program assumption on development goals, is present.

The other models and techniques that have been used in the past for less comprehensive sector studies are too numerous to deal with fully in this report, but there are several which deserve special mention, either because of their relevance to specific questions encountered in sector analysis which call for

special techniques, or because of their value in helping the sector analyst better understanding the sector with which he is dealing. Although a number of these are economic models, operations research models are included as well.

Farm Models. Deserving special attention are the farm models, for they attempt to get at key questions of farm and farmer behavior. Farms have been modeled in several ways, among them farm management accounting models; linear programming models; and system simulation models.

The accounting model consists principally of an accounting of the inputs and outputs of the farm, usually in both physical and monetary terms. Such an accounting can be compared with similar accountings for model farms or for statistically derived averages, thus giving the analyst some idea of where the farm stands in a given population or in relation to some standard.

The linear programming model is based on the economic theory of the firm, or on some suitably modified theory. The model uses data similar to that in the accounting model, but enables farm behavior to be simulated under varying conditions, such as changing amounts of land, labor, or capital. Models are used which assume that the farmer operates his farm in such a way as to maximize profits as well as with other objective functions; e.g. minimizing the cost of attaining some specified production (and/or consumption) target. These LP models can be designed to simulate a single crop season; and entire year of crop seasons, or crop cycle; or several years of production. A variant that has been developed recently is that of recursive

linear programming, which includes several crop cycles and allows dynamic behavior.

Not much attention has been given to the construction of a systems-simulation models at the farm level, but a notable example to the contrary is a study of farming at the village level in India, by Arthur Dommen (4, 1974). The study is not a farm model *per se*, but the technique could be easily adapted to the modelling of individual farms.

Production Functions. The production function is a model which embodies the economic theory of how producers allocate resources to produce a given commodity or bundle of commodities. The form of the function usually follows one of two or three forms which have become standard in economic theory, and coefficients for the function are estimated statistically.

Operations Research Models. There are several operations research models, so-called because of the techniques which are used, which occasionally provide valuable information for sector analysis efforts. Among these are inventory models, which can be used to model capital accumulation in activities such as livestock or tree crops. An interesting operations research model was designed for the analysis of coffee in Center America by Gilberto Paez of the Instituto Interamericano de Ciencias Agrícolas, in Turrialba, Costa Rica. The model uses the technique of factor analysis to determine the locations within each country in which the rust, if it appears, will be most likely to spread the fastest, based on knowledge of climatic and ecological factors.

The Subsistence Subsector. Most of what we have discussed here so far has been the result of study of the commercial sector. Because there are clear manifestations of the activities of the commercial sector through the marketing of its products, plentiful data on quantities produced, market prices, etc. are available, and the linkages between the various elements in the production and consumption of goods produced can be traced with some ease. Not so in the subsistence sector. Here the activities of production and marketing are harder to observe, because there is no way for information regarding production and other transactions to be recorded in a permanent manner except by means of purposive, firsthand investigation at the farm level, a fact that severely limits the quantities of data at hand.

But these activities assume a role of importance when our goals refer to the poor majority in developing nations. In most cases the majority of the population in developing countries live in rural areas, and in general per capita annual income is considerably lower there than in urban areas, even aggregating population and income data for both the subsistence and commercial subsectors. This is thought to imply a lower average level of living in the rural areas, even taking into account the "self-sufficiency" aspect of rural life.

We are faced with two attendant problems in trying to deal with policies and programs to meet the needs of the population of the subsistence subsector. The first is that we have less accurate knowledge about the production and consumption habits

of this population for the reason mentioned above, and consequently are less able to specify what kinds of projects will have desired effects than in the case of the commercial subsector. The second is that the mechanisms which are frequently used to reach the commercial farmer (credit programs, technical assistence efforts operated through suppliers of inputs, and so on) have only limited abilities to reach the subsistence farmer. He is cut off from many of the communication channels and energy channels open to his commercial counterpart. On the whole, it may be a very wasteful mistake for policy-makers to assume that the subsistence subsector behaves like the commercial subsector.

Because of these difficulties, different methods of analysis need to be applied to the problem of the subsistence subsector. There have been a few efforts along these lines, but not much has been incorporated into the sector analysis efforts of the past few years. Among the techniques that have been used are sample surveys for the establishment of data bases, involving both production and consumption activities, and the construction of models at the farm level for the study of subsistence farms in terms of minimum viable farm size, level of technology, labor utilization, etc. There are design problems concerning the surveys that have been used to study subsistence agriculture. In most cases they are either the same, or slightly modified versions of surveys used for the provision of data on commercial farms. While these surveys may serve for some of the subsistence farmer, in other cases they serve for little.

Careful study of the subsistence subsector is needed for more than one reason. Many people assume that subsistence agriculture has no role in the development process. It is argued by them that we need to find ways to either move the subsistence agricultor into the commercial markets, or get him off the farm and into kinds of economic activity that will provide a higher income than he currently earns. Others argue quite the opposite, that there are opportunities in the subsistence subsector which we are not exploiting, and that we should be trying to find ways to make subsistence agriculture more able to serve the needs of the people who inhabit it. It is our opinion that neither position represents the only viable alternative de natura, but that in every country, and even within given regions and districts of the same country, the exact way in which the subsistence subsector fits into the picture of social and economic development must be determined from a careful analysis of its characteristics. Such an analysis must include geographic and climatic factors, as well as additional information regarding a host of other variables, such as population densities, soil quality, distances from population centers, and patterns of economic activity in those centers. Habits of production and consumption on the part of the subsistence producers must be studied. In short, there is a need for a 'subsector analysis' of the subsistence subsector before decisions can be made about this problem.

Addressing Nutrition Concerns. Although nutrition *per se* has been addressed in only a few agriculture studies (See [22, 1975], [24, 1975] and [22, 1974]), variable, such as income, know to be associated with nutritional problems have been addressed in many studies.

We have stated that nutritional status in developing countries is primarily a function of two things: (1) the amount and quality of food ingested; and (2) the efficiency with which the body utilizes the food consumed. In the case of the first, above, quantity and quality of food consumed are determined by a series of related factors, among which are:

1. Family income;

2. Food habits, including those which affect the kinds of foods eaten or proscribed, intrafamiliar food distribution, methods of food preparation, breast feeding patterns, etc.;

3. Level of education;

4. Availability of food items and their relative prices.

The efficient utilization of food consumed is in part conditioned by the quality of the food eaten, but more strongly by the occurrence of infectious disease. The frequency of occurrence of such illness is largely an environmental matter, with the availability of potable water and the adequacy of the infrastructure of sanitation being primary determinants, along with the adequacy of provision of preventive health services. Our discussion here will treat some of these factors.

Family income. The influence of family income on nutrition can be viewed from two different levels in sector analysis: from

the level of the sector and from the level of the individual producer and consumer. The choice of the former view has often been dictated by a concern for determining the aggregate income changes induced by changes elsewhere in the sector. The choice of the latter has often been dictated by a concern for such microeconomic aspects of behavior as the income elasticities of various foods, which can relatively easily be translated into nutrition effects by the simple application of nutritive-value coefficients; these latter aspects are firmly grounded in the theory of consumer behavior, and are thus basically a part of the study of individual producers and consumers. It is evident that as the farmer in the subsistence subsector is both a producer and a consumer of foods, his behavior will manifest the often conflicting effects of changes in the prices of staple foods, of which the consequent change in his income (or purchasing power) is one. More will be said about this below.

Among efforts to incorporate family income effects into sector-level analysis, income classes were built into both input-output and linear programming models of the agriculture sector of Colombia undertaken by the Sector Analysis Division of the Latin America Bureau of AID. In the input-output model, the linkages between various income classes and production activities were direct, and the model was able to produce estimates of total income by income class for different policy and program assumptions input to it. Similar classes were built into the linear programming models of the sector, enabling the analyst to determine how sector production activities and resources should be allocated in order to have maximum impacts upon income for certain of the

income classes. Thus income distribution effects of various policy and program alternatives could be estimated, both for the agriculture sector and for other sectors.

The Colombia Sector Analysis also included analysis of producer income at the farm level, directed especially at the small farm. This was accomplished through the use of farm level linear programming models. Analysis of the impacts of levels of technology, land and labor utilization, and the availability of operating capital upon the income of the farmer were carried out through the use of these models.

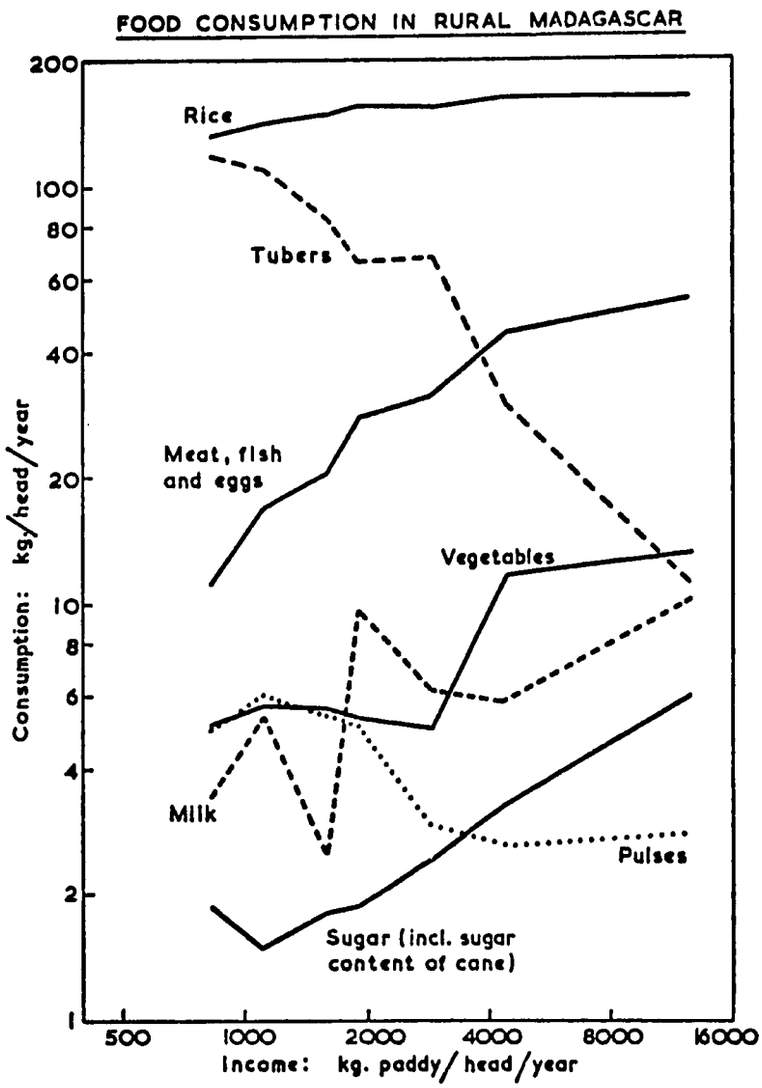
Other studies have treated the problem of income and income distribution as well. Estimates of employment and income for agriculture and non-agriculture were obtained in the sector analysis of Guatemala by Fletcher, Merrill, et al described previously. The sector model of the Ivory Coast produced by the World Bank also includes income distribution concerns.

The focus on microeconomic analysis of family income effects has had its justification in the recognition of the fact that income level has an important bearing on people's eating habits (see Fig. 5 for some typical data from Madagascar). "Average" figures are, therefore, misleading when it comes to the analysis of the interaction of income and nutrition.

In Guatemala, the lowest 30 per cent of the population in income terms consumes an average of 1615 calories and 39.7 grams of protein, both representing serious nutritional deficiencies. Aggregate consumption figures show that for the population as a whole, consumption was 2184 calories and 60.5 grains of protein.[1/]

1/ Rene Arturo Orellana and A. E. de Leon, Ingresos y Gastos de Familias Urbanos de Guatemala; IIES, Guatemala City, 1972.

FIGURE 5.



Source: Colin Clark and Margaret Haswell, The Economics of Subsistence Agriculture (London: Macmillan, 4th ed., 1970), Chart XIX, p. 189.

Estimates of food consumption for Nicaragua were made by GAFICA (Grupo Asesor de FAO para la Intergracion Centro Americana) in 1970, according to income group. While overall consumption was 2380 calories and 64.2 grams of protein, the consumption figures for the lower 50 per cent of the population in income terms were 1767 calories and 46.6 grams of protein.[1/]

As a result of this recognition, models in the agriculture sector have begun to incorporate food consumption in ways which show variation by income class. Such disaggregated data are not always available for rural populations, but when they are they are capable of providing much insight (see, e.g., [11, 1972], based on the sample of 9,694 households included in the 1969-70 Socio-Economic Survey in Ceylon, in which six income categories have been used). Models built by I. J. Singh and M. S. Mudahar have focused on the problem of income at the farm level, and have moreover added subsistence consumption requirements as constraints.

Margaret Andrews has developed a farm model which incorporates income, consumption, and nutrition activities. By including all of these as endogenous activities, the interrelationships among the various types of activities can be studied. The model is cast in a linear programming framework.

The differential effects on small farmers' consumption of home-produced foods and purchased foods of the terms of trade between agricultural and non-agricultural products have been established by Tendulkar [5, 1979]. Using monthly data on value of consumption and value of cash purchases by a sample of

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1/ Unpublished GAFICA figures. See [3, 1976].

cultivators in Uttar Pradesh, India, and a "parity index" of the ratio of farm prices to purchase prices of non-agricultural commodities, Tendulkar found an "asymmetrical impact on cash and non-cash components" of consumption. In terms of the present discussion, the relevant point is that, beyond family income, the purchasing power of things small farmers sell exerts an influence on their consumption behavior, and therefore on their nutritional well-being.

For his analysis of the income and substitution effects of price relationships on the consumption behavior of the farmers in the sample, Tendulkar used a dynamic consumption function first developed by Houthakker. Let q(t) be the instantaneous rate of consumption of a good; x(t) be the instantaneous rate of income; p(t) the price of the good; and s(t) a state variable, all at time t. Then:

$$q(t) = \alpha + \beta s(t) + \gamma x(t) + \lambda p(t)$$

For a durable good like furniture, the state variable s(t) may be thought of simply as the level of inventory of furniture and it is plausible that the sign of β will be negative. This would also plausibly be the case if the good in question were a storable food like wheat grain or flour and q(t) were cash purchases of this good rather than consumption, as is the case in some of Tendulkar's regression equations. More generally, however, s(t) may be considered to be an unobservable variable encompassing not only inventories but also psychological states which affect consumption of goods like smoking tobacco where current consumption is more dependent on habits than on inventories. The sign of β may thus be seen to be either negative (inventory behavior) or positive (habit behavior).

The difficulty entailed by the non-observability of the state variable s(t) is overcome in the Houthakker-Tendulkar model by mathematical transformation of the equation to be estimated. In this transformation, one-period lagged observations of consumption, income and prices and one-period changes in income and prices end up on the right-hand side, and s(t) disappears. Tendulkar used various commodity groups as his dependent variable, also making use of the cash versus non-cash distinction provided by his data. Unfortunately, the data, while impressive for the length of the time series (July 1957-June 1963), lacked a series on income, and so Tendulkar chose to use total expenditure as a proxy, a device that must be surmised to have considerably reduced the reliability of the results obtained in his equations using the cash and non-cash components of total expenditure, respectively, as dependent variables. Also lacking, as he notes, were data on size and age composition of the sample households, wealth and liquid assets, etc., which might also plausibly be considered relevant variables in the model. In spite of these drawbacks, Tendulkar's study shows what could be done, given adequate and relevant data, in the way of analyzing the effects of family income on nutrition among small farm households.

In his model, Tendulkar was led to treat home-produced foods as income and expenditure goods (his data imputed a value to home consumption of such goods, and he implicitly treated them as a form of income by taking total expenditure as a proxy variable for income). This is a reasonable approach, for in the subsistence subsector money changing hands is not always the most appropriate measure of income.

Arthur Dommen has constructed a systems simulation model of a village in India in which a level of living variable subsumes money income and home consumption, and is measured in terms of grain equivalents. Such extended notions of family income seem to hold promise for use in further research in this area.

Food Supply. The problem of food supply is, of course, central to agriculture sector analysis and planning, and therefore all sector studies devote considerable attention to it. But there have been several efforts to deal with food supply in nutritional terms. Notable among these is the work of R. E. Suttor, who has dealt both with food supply, income distribution and their interrelationships in the Colombia sector analysis referred to earlier. Suttor developed a linear programming model of the agriculture sector, and included in the model equations for translating food balances into nutrients: calories, essential amino acid groupings; and vitamins and trace minerals. The impact of a given set of program alternatives could thus be translated directly into nutrition terms. The model also includes food consumption activities, stratified by income groups, allowing the relationships between income and food consumption to be analyzed.

The work of Victor E. Smith includes a study of the Nigerian agriculture sector, focusing on the agriculture-nutrition interface. The work is based on a mathematical programming model in which are included various production alternatives, trade activities internal to the country, and activities for the importation of food. The model is subdivided into six distinct geographic

regions for production and consumption, and each of 14 nutrients is specified in certain amounts for consumption purposes, on a regional basis. The model is used to determine the production pattern which would maximize the income to be earned from the production of goods not used for food within Nigeria, subject to the given nutritional constraints. This use of the model has as its primary objective meeting nutritional needs, but allocates resources in such a way as to accomplish this with the smallest possible sacrifice of income from non-food activities.

A separate study of Nigerian agriculture, carried out by a team of Michigan State University analysts, and based on a simulation model framework, included among its considerations the estimation of calorie production under alternative assumptions in policy and program terms.

A recent effort by Pinstrup-Andersen et al makes the attempt to determine commodity priorities by estimating the impact upon human nutrition of different types of food supply changes [5, 1976]. Income elasticities of demand are estimated for each of 22 foods consumed by each of five income strata, from a sample of 230 urban families. A complete price elasticity matrix is then estimated for each of the strata. The effect of a 10 per cent horizontal shift in the supply curve of each food is then calculated, keeping the supply curves of the other 21 constant. Lastly, they measure the nutritional impact of the resulting changes in consumption, using three sets of indicators: (1) the percentage of the total supply increase of the food consumed by the nutrient-deficient strata of the population; (2) the change in per capita

calorie and protein intake by deficient strata; and (3) the percentage reduction in total calorie and protein deficiencies. This then permits the authors to rank the different foods according to their efficiencies under three sets of assumptions concerning the costs associated with the supply changes. They find some surprising results: for instance, increasing the supply of peas and tomatoes was found to reduce the total calorie intake for the nutrient-deficient strata, while protein intakes would decrease by increasing supplies of oils and fats.

The assumptions underlying the study make the technique valid then only under certain conditions, but the approach certainly addresses issues appropriate to nutrition planning, and to agricultural planning as well.

Prices. Prices of food items play a central role in both producer and consumer decisions. The care with which prices are treated in most agricultural sector studies is not commensurate with this level of importance. Data of sufficient richness and timeliness concerning food prices is seldom collected, although there is no methodological bottleneck to doing so. One frequently finds reasonably complex production analyses tied to consumption by a thin thread composed of a few hastily constructed, or borrowed, price and/or income elasticities.

The importance of prices in food consumption behavior is illustrated in a recent study by Andrews and Poynor [1, 1976]. The work cited uses a very simple model of urban food consumption behavior, and obtains striking results. Food consumption is assumed to be a function of three things: (1) a preferred, or ideal, diet, which the consumer will purchase and consume if this

is possible; (2) family income levels; and (3) retail food prices. The actual form of the model is that of linear programming. Family food purchases are predicted by minimizing the difference between the ideal diet of the family, and what income and price considerations dictate may actually be purchased. The notion of difference in the model is that of difference in absolute quantity.

Other studies have found income to explain less than half of the variation in calorie and protein intake observed in urban diets [20, 1975]. For the samples used in the study under discussion, about 95 per cent of the variation was explained by the combined use of income levels and retail food prices. The countries studied were Bolivia, Colombia, and Dominican Republic, and Guatemala.

The problem of determining the impacts of prices on rural food consumption is much more complex, since in rural areas both production and consumption decisions respond to prices. Although a number of micro-level studies have addressed this problem indirectly, notably those of Suttor [23, 1973], Singh [20, 1973], and Andrews [5, 1975], only the work of Andrews has included both production and consumption decisions as endogenous concerns in the models used. At the sector level, the Mexico CHAC model of the agriculture sector has the capability of determining price levels endogenously, and therefore allows for the impacts of policies upon prices to be analyzed.

Food and nutrition planners make extensive use of food balance sheets in their determination of future policy and program parameters. Disaggregation of these balances has shown,

however, that they mask a great deal of the variation in food 'availability' observed when food consumption is studied as a function of income. GAFICA, working with the Secretariat for Central American Economic Integration (SIECA), has developed a method for regrouping food balances by income group. The methods redistributes food balances to four income classes: (1) the lowest 50 per cent of the population in income terms; (2) the next 30 per cent; (3) the next 15 per cent; and (5) the top 5 per cent in income terms. The exact method for this distribution is unpublished, but involves allocating food to the various groups on the basis of food prices, income and population levels within the groups, and the observed eating habits of the various groups. The resulting food balances are labeled 'apparent consumption' by the GAFICA analysts. They are used for projecting food balances by income group into the future. The results agree very well with what is known on the basis of food consumption and expenditure studies. The technique deserves to be more widely known and utilized.

One of the problems which exists in the use of food balances for food and nutrition planning, even when they contain disaggregate balances by income class, is the time required for their preparation. It is not unusual for the balances to require three or more years to be prepared. This severely limits their utility as a planning tool, since it requires them to be used as a retrospective device. This is a little like driving a car by looking in the rear view mirror. It is especially difficult during periods when significant changes in resource costs and availabilities are being experienced.

A more useful tool for planning purposes would be the

preparation of short term projections into the future (for a 1-3 year planning horizon) of food and nutrient balances, broken down according to income groups, with different projections made under different policy and program assumptions. There are two different methods available for making this type of projection. The first method is that mentioned above as having been developed by GAFICA. It suffers from the limitation that base line data on food balances must be used in the preparation of the projections. If it takes three years after the fact for this data to become available, then a three year projection horizon is required to project the results to the present.

A second method which can be used has several distinct advantages. This is the use of a sector agriculture model for the projections. We noted earlier that at least three of the existing types of sector models have the capacity to project food supply, in terms of either individual food commodities or groups of commodities, under alternative sets of policy and program assumptions. With this capability it is possible to make projections of food and nutrient balances. This technique is more powerful than the previous method discussed, because of the greater flexibility of the model in examining the results of various assumptions. Another advantage is that of computational ease. With a sector model operational, the necessary computer software for making projections is already available.

When attempting to discuss regional patterns of food distribution and consumption, nutrition planners are frequently forced to use agricultural production by regions as a proxy for consumption. This, of course, gives worse than useless results

in many cases. In the place of this, a simple network analysis of the commercial marketing channels, with estimates of the magnitude of commodity flows, would give much better results. Such an analysis could easily be complemented by estimates of foods marketed outside of the commercial marketing channels, to arrive at regional or areal estimates of food availabilities. The kind of information asked for here is central to good agricultural planning, and therefore something that should be provided as a matter of course for agriculture sector analysis.

The kind of information mentioned in this last paragraph can be used in the construction of regional agricultural models. Because of the varying terrain, climatic zones, soil characteristics, and other factors, agriculture in the developing world cannot be treated as a monolithic entity. It is important for both agriculture and nutrition analysis that regional specificity be available for planning programs and developing meaningful policy.

Our final two comments concern the development of methods for examining the effects upon the income distribution of various policy and program alternatives, and analysis of the character of behavior of those families who are both producers and consumers of food. With regard to the first, we see no way that income distribution effects can be successfully addressed without the use of sector models. With regard to the second, it is the small scale producer who most needs to be understood. He is frequently caught between conflicting patterns of behavior, with the need to sell his product in order to satisfy his need for consumption income, and his need to have a constant supply of cheaply produced food.

The small farm has typically been viewed for purposes of analysis in much the same way that the large industrial enterprise is viewed, as an embodiment of the economic principle of maximization of net returns, in one form or another. Empirical and theoretical studies of the past few years have called into question, if not the economic principle as applied to these producers, at least the way returns are measured, and the appropriate variables to be included in the models used. Reference is made in this regard to the following: [4, 1975]; [5, 1975]; [4, 1974]; [13, 1974]; [16, 1973]; and [20, 1973].

A final comment concerning the use of agriculture sector analysis methods concerns the difficulty of putting into play the kinds of data analysis mechanisms required to build and use sector models. The analyst of the earlier period of development and use of these models was faced with considerable pain in the use of the computer. In recent years the software associated with the development and use of sector models has been improved a great deal. The Worl Bank, in particular, has pioneered with software designed especially to simplify and shorten the task of developing sector models. Today an analyst can construct and test a model in a few weeks that would have taken as much as several man-years of professional time only a few years ago.

With this new ease of use of sector analysis methods, we are on the threshold of a new surge in the application of these methods to the needs of agriculture planning. With only a little effort these methods offer much utility as well for addressing nutrition concerns.

APPENDIX

The reader who is interested in an exhaustive treatment of the techniques and models reviewed here can find such treatment for most sector analysis models in the individual reports listed in the bibliography at the end of this appendix. In this technical appendix we include descriptions of several of the models referred to earlier which will satisfy most questions concerning the details of design and construction of the models.

The following are included:

- A regionalized linear programming model for Portugal
- A general equilibrium-consistency model for Panama
- An agriculture-oriented input-output model for Colombia
- A farm model with endogenous consumption activities for the Dominican Republic
- A simulation model for a village in India
- A recursive programming model for Punjab
- Production functions
- Demand Projections

A REGIONALIZED LINEAR PROGRAMMING MODEL FOR PORTUGAL

This sector model for Portugal [5, 1974] is formulated subject to the following assumptions:

a. There are 'n' distinct spatially located regions of production;

b. Within these regions there are 'z' rational producers whose main decision criterion is to maximize profit

c. These units because of their homogeneity can be aggregated into 'm' macro units which can be represented by linear programming activities;

d. Within the regions there are 'q' consumers who also include producers of agricultural products. These consumers have certain incomes which are used to buy,

among other things, food products. The level of consumption of these products is determined by consumer income and price;

e. There exist processing facilities which transform agricultural raw materials into consumption goods;

f. There are middle men who buy from producers and sell to consumers and who try to maximize their margins.

The variables are:

S = Final product sales activity

Λ = Social payoff

M = Processing activity

P = Primary product producing activity

T = Transport activity

IM = Import activity

EX = Export activity

PD = Domestic price

The constants are:

EP = Export price

IP = Import price

C = Production cost

R = Basic resource

PC = Processing, handling, and selling cost

t = Transport cost

a = Input coefficient

b = Output coefficient or secondary input coefficient

I = Income

K = Demand segment constraint

The indexes are:

j = Region, j = j = 1, 2, 3, ..., 11

i = Final product, 1 = 2, 3, ..., 22

p = Primary product, p = 1, 2, 3, ..., 19

m = Processing m = 1, 2, 3, ..., 23

r = Basic resource, b = 1, 2, 3, ..., 12

n = Demand

The Objective Function is:

$$\begin{aligned} \text{Max } f(w) = & \sum_i \sum_j S_{ij} \; \Lambda_{ij} \; (S_{ij} I_j) \\ & + \sum_{ij} (EP)_{ij} \; (EX)_{ij} - \sum_{mj}\sum (PC)_{mj} M_{mj} - \\ & \sum_{pj}\sum C_{pj} P_{pj} - \sum_{ij}\sum (IP)_{ij} (IM)_{ij} \qquad (1) \\ & + \sum_{pjj'}\sum\sum T_{pjj'} - \sum_{ijj'}\sum\sum T_{ijj'} \; t_{ijj'} \\ & - \sum_{rjj'}\sum\sum T_{rjj'} \; t_{rjj'} \end{aligned}$$

The solution to equation (1) gives the classical static, competitive, spatial equilibrium solution for the economy in which marginal cost (including direct and opportunity cost) equals the price for each commodity in each region.

The maximization of equation (1) is constrained by resource availabilities and certain other conditions as follows:

$$R_{jr} \geq \sum_p a_{pjr} P_{pj} + \sum_m a_{mjr} M_{mj} + \sum_{\substack{j \\ (j \neq j')}} T_{rjj'} - \sum_{\substack{j \\ (j \neq j')}} T_{rjj'} \qquad (2)$$

$$0 \geq \pm b_{pjm} P_{pj} + M_{mj} + \sum_j T_{pjj} \; {}_{(j \neq j')} - \sum T_{pjj} \; {}_{(j \neq j')} \qquad (3)$$

$$0 \geq -b_{ijm} M_{mj} + S_{ij} + \sum_{\substack{j \\ (j \neq j')}} T_{ijj} - \sum_{\substack{j \\ (j \neq j')}} T_{ijj} \qquad (4)$$

$$S_{ij},\ M_{mj},\ P_{pj},\ (IM)_{im},\ (EX)_{ij},\ P_{ij}\ T_{ijj} \geq 0 \qquad (5)$$

In summary, these constraints require that the level of resource R in region j cannot exceed current availability plus net imports (2); the amount of raw material R for processing activity M in region j cannot exceed that produced in the region plus net imports (3); the amount of final product S_i sold cannot exceed production plus net imports in each region (4); the value of all variables must be non-negative.

The pseudo-constraints which approximate a non-linear demand function by linear segments with convex constraints are of the form $K_{ij} \geq k_{ijn} S_{ijn}$ (6)
such that the weighted sum of product i sold in region j cannot exceed consumption upper bound K_{ij}, where K_{ij}/k_{ijn} is the maximum amount of commodity i that can be sold through segment n in region j.

Finally, for some analysis the following constraint is used for agricultural products:

$$0 \geq -\sum_{ij}\sum (EP)_{ij}\ (EX)_{ij} + \sum_{ij}\sum (IP)_{ij}(IM)_{ij} \qquad (7)$$

$$\sum_{j} (EX)_{ij} \leq E_i \qquad (8)$$

$$\sum_{j} (IM)_{ij} \leq I_i \qquad (9)$$

Summary of Specific Structure

I. Solution Objective: Economic efficiency, i.e., marginal cost = price for all products and all regions

II. Eleven Programming Regions

III. Regional Demand Functions for All Final Products: q=f(P,I) where q is per capita consumption, P is price and I is income

(1)	Wheat products	(12)	Wine
(2)	Corn products	(13)	Olive oil
(3)	Milled rice	(14)	Oranges
(4)	Rye products	(15)	Beef and veal
(5)	Barley products	(16)	Pork and lard
(6)	Oat products	(17)	Lamb and mutton
(7)	Dry beans	(18)	Milk
(8)	Broad beans	(19)	Butter
(9)	Chick peas	(20)	Wool
(10)	Potatoes	(21)	Non-fat dry milk
(11)	Tomato products	(22)	Cheese

IV. Intermediate Products:

(1) Low protein feed concentrates-corn, oats, and barley
(2) High protein feed concentrated-oilseed meals, skim milk
(3) Animal power
(4) Milk
(5) Forage

V. Primary Products

(1)	Wheat	(11)	Grapes
(2)	Corn	(12)	Dry beans
(3)	Rye	(13)	Oranges
(4)	Rice	(14)	Beef cattle and calves
(5)	Oats	(15)	Swine
(6)	Barley	(16)	Sheep and lambs
(7)	Broad beans	(17)	Wool
(8)	Chick peas	(18)	Sheep milk
(9)	Potatoes	(19)	Cow milk
(10)	Olives		

VI. Production Activities:

A. Crops - three production technologies: (1) mechanized (2) non-mechanized, and (3) partially mechanized

1. Rotation Crops

(1)	Wheat	(7)	Broad beans
(2)	Corn	(8)	Chick peas
(3)	Rice	(9)	Potatoes
(4)	Rye	(10)	Grapes
(5)	Barley	(11)	Dry beans
(6)	Oats		

2. Non-rotation Crops
   (1) Grapes (2) Olives (3) Oranges

B. Livestock

1. Livestock Activities
   (1) Animal power - mules and bulls
   (2) Beef cattle
   (3) Dairy cattle
   (4) Swine
   (5) Sheep

2. Primary Output
   (1) Slaughter animals
   (2) Milk
   (3) Wool
   (4) Animal Power

VII. Processing Activities:

All basic products, except forage.

VIII. Internal Trade Activities:

All basic products, except wool, tomatoes and non-fat dry milk, plus cheese and butter, and pasturized milk for regions 3 and 6.

IX. Foreign Trade Activities

A. Imports
   (1) Wheat and products
   (2) Corn and products
   (3) Milled rice
   (4) Potash Fertilizer
   (5) Beef
   (6) Pork
   (7) High protein foods
   (8) Butter

B. Exports
   (1) Wine
   (2) Olive Oil
   (3) Lamb
   (4) Tomatoes

X. Regional Resource Constraints

A. Land in hectares
   (1) Irrigated
   (2) Class A
   (3) Vineyards
   (4) Olive trees
   (5) Orange trees
   (6) Other land

B. Labor - available man-hours by quarter

C. Tractor power - available hours by quarter

D. Slaughter house capacity - tons in critical months

E. Milk processing capacity - tons in critical months

F. Butter and cheese processing capacity - tons in critical months

G. Meat cold storage capacity - tons, cumulative requirements based on slaughter and consumption patterns

H. Fertilizer plant capacity - tons per year

A General Equilibrium-Consistency Model for Panama

This framework for sector analysis consists of two models used in conjunction in a consistency framework to obtain consistent projections of sectoral output and employment. The two models used are an aggregative macroeconomic model and an imput-output model for the Panamanian economy [15, 1975]. The figure below illustrates schematically how the framework is structured.

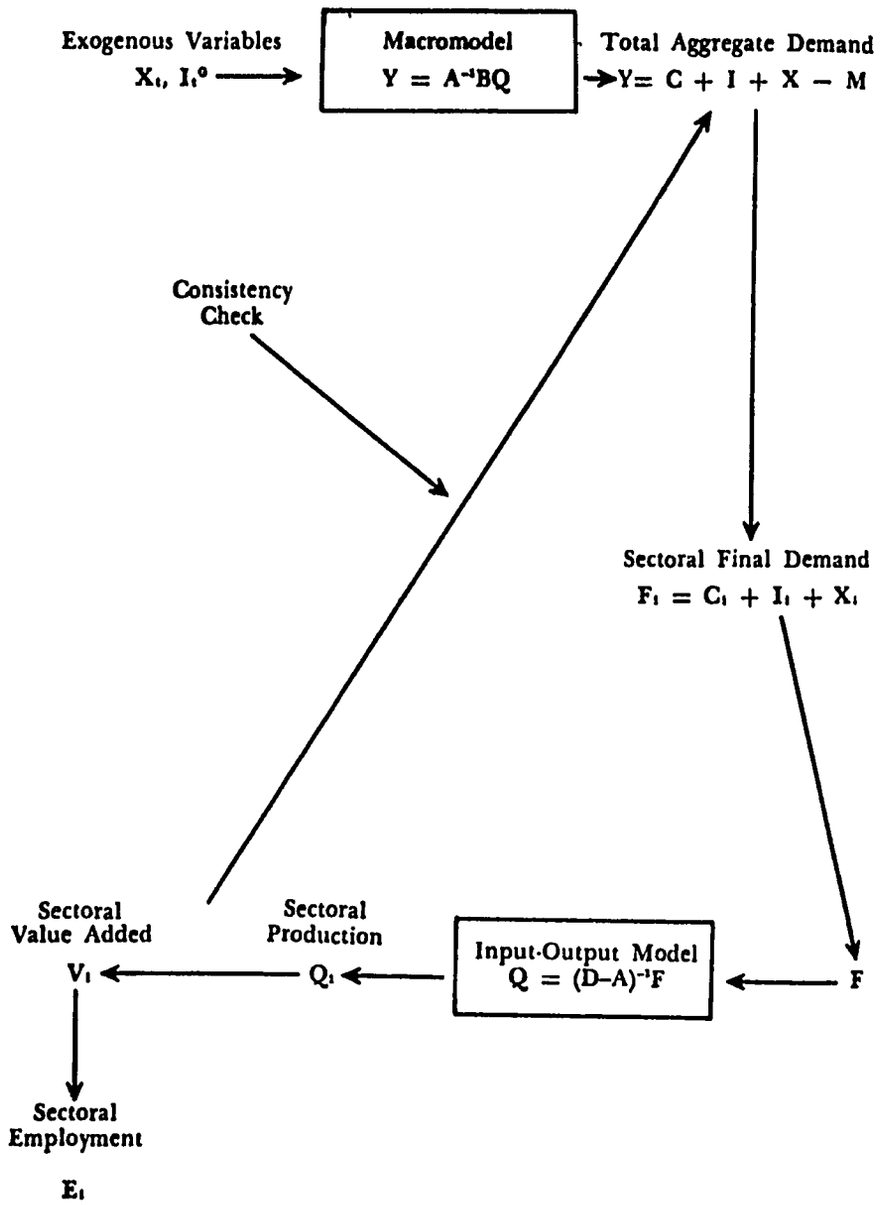

Figure 2 . Panama: Consistency between Overall and Sector Growth Rates.

The Macroeconomic Model

The endogeneous variables are:

CP = Private consumption

YD = Personal disposable income

IP = Private investment expenditure

CG = Government consumption expenditure

Y = Gross domestic product

ΔS = Change in inventories

M = Imports of goods and services

C = Total consumption expenditures

TD = Direct taxes

TI = Indirect taxes

The exogeneous variables are:

X = Total exports of goods and services

IG = Government investment expenditures

The parameters to be estimated are: a, b, c, d, e, f, g, h, i, j, and k; t is the time index.

The equations of the aggregative model which are estimated by ordinary or two-stage least squares follow:

$$CP_t = aY_t + bC^P{}_{t-1} \quad (1)$$

$$IP_t = -c + d\,Y_{t-1} \quad (2)$$

$$CG_t = eY_t \quad (3)$$

$$\Delta S_t = f\cdot(Y_t - Y_{t-1}) \quad (4)$$

$$M_t = gC_t + hI_t \quad (5)$$

$$TD_t = -i + jY_t \quad (6)$$

$$TI_t = KY_t \quad (7)$$

The accounting identities which complete the system are:

$$C_t = CP_t + CG_t \tag{8}$$

$$Y_t = CP_t + IP_t + S_t + CG_t + IG_t + X_t - M_t \tag{9}$$

$$YD_t = Y_t - TD_t - TI_t \tag{10}$$

$$I_t = IP_t + IG_t \tag{11}$$

The Input-Output Model

The Leontief I/O model used consists of 10 sectors:

a. Agriculture, including forestry, hunting, and fishing

b. Mining and quarrying

c. Food manufacturing, including beverages and tobacco

d. Nonfood manufacturing

e. Construction

f. Utilities

g. Commerce, including storage, communications, and transportation

h. Finance

i. Housing

j. Services (public and private, including public administration)

Thus GDP is composed of ten types of goods. The total supply of goods of any type is equal to domestic production plus imports:

$$S_i = Q_i + M_i, \quad i = 1,\ldots,10 \tag{12}$$

where S_i = total supply of goods of type i

Q_i = total domestic output of sector i

M_i = imports of goods of type i

The total supply of goods of type i is equal to the sum of intermediate demands from all sectors (including sector i) and the final demand for type i goods. This sum is given by equation (13).

$$S_i = \sum_j S_{ij} + F_i \tag{13}$$

Where F_i = final demand for goods of type i. It is assumed that the domestic output of sector i is a constant proportion (U_i) of total supply of goods produced in the sector. Likewise, a fixed amount of good i is required to produce one unit of good j.

Thus

$$\frac{Q_i}{U_i} - \sum_j a_{ij}Q_j = F_i \tag{14}$$

where:

$$F_i = CP_i + IP_i + CG_i + IG_i + X_i \tag{15}$$

and i is an index of goods.

Equation (15) can be rewritten as a system of equations with matrix representation as follows:

$$(D - A)\ Q = F \tag{16}$$

where D is a diagonal matrix of the inverses of the (U_i) proportion constants, A is an i x j matrix of (a) input-output coefficients, Q is a diagonal matrix of the (Q_i) output levels, and F is a matrix of the system of (F_i) final demand equations.

The matrix inverse of D-A is taken and multiplied by equation (16) giving

$$Q = (D-A)^{-1}F \tag{17}$$

which is used to calculate gross output of each sector given data and projection from the macro economic model for final demand for goods from each sector.

Sectoral value added is assumed to be a constant proportion (a) of gross sectoral production such that (in matrix form)

$$V = a\ (D-A)^{-1}F \tag{18}$$

where V is the value added sector and a the diagonal matrix of proportion elements.

Finally, it is assumed that average labor productivity is constant in each sector and employment by sector is derived from equation (19).

AN AGRICULTURE-ORIENTED INPUT-OUTPUT MODEL FOR COLOMBIA

A rather large input-output model was constructed as part of a sector analysis of Colombian agriculture carried out by the Sector Analysis Division of the Latin America Bureau of AID [4, 1972]. The model serves several purposes, among them:

a. To provide estimates of indirect, general equilibrium impacts of program alternatives;

b. To provide a framework for testing the reliability of data;

c. To allow analysis of intersectoral impacts of investment alternatives.

The sector delimitation scheme for the model is as follows:

Sector	Probable Number of Activities, Second Model
Primary Agriculture	200
Agricultural Processing	120
Agricultural Inputs	25
Primary non-agriculture	4
Industry	40
Services	20
Construction	9
Transportation	7
Marketing - Wholesale	35
Marketing - Retail	35
Government	10
Households	40
Import - Export	20
Capital	25
Inventories	10
TOTAL	600

In 1971-72 the first series of models were constructed, using 1967 data. The total number of activities was approximately 250, with about 100 being in primary agriculture and 25 representing households. Thus, about half of the activities were agricultural and household activities.

A second input-output study was begun soon after the first set of models were completed. Plans call for about 600 activities to be included, as shown in the table above.

The basic structure of the model is discussed briefly in the Panama case of the preceding section.

Households are broken down by income groups in the model, and thus, income distribution effects of investment alternatives can be traced using the model. The scheme for including households is shown in Figure 3 . The household sector provides both labor and capital services to the other sectors in the model, and as a result income flows include payments to land, labor and capital.

Documentation for this work appears in a series of Working Documents produced in conjunction with the Colombia sector analysis. A complete list of these is available in General Working Document # 101, Bibliography, Sector Analysis Division, LA/DR, Agency for International Development, Washington, D.C., 1974.

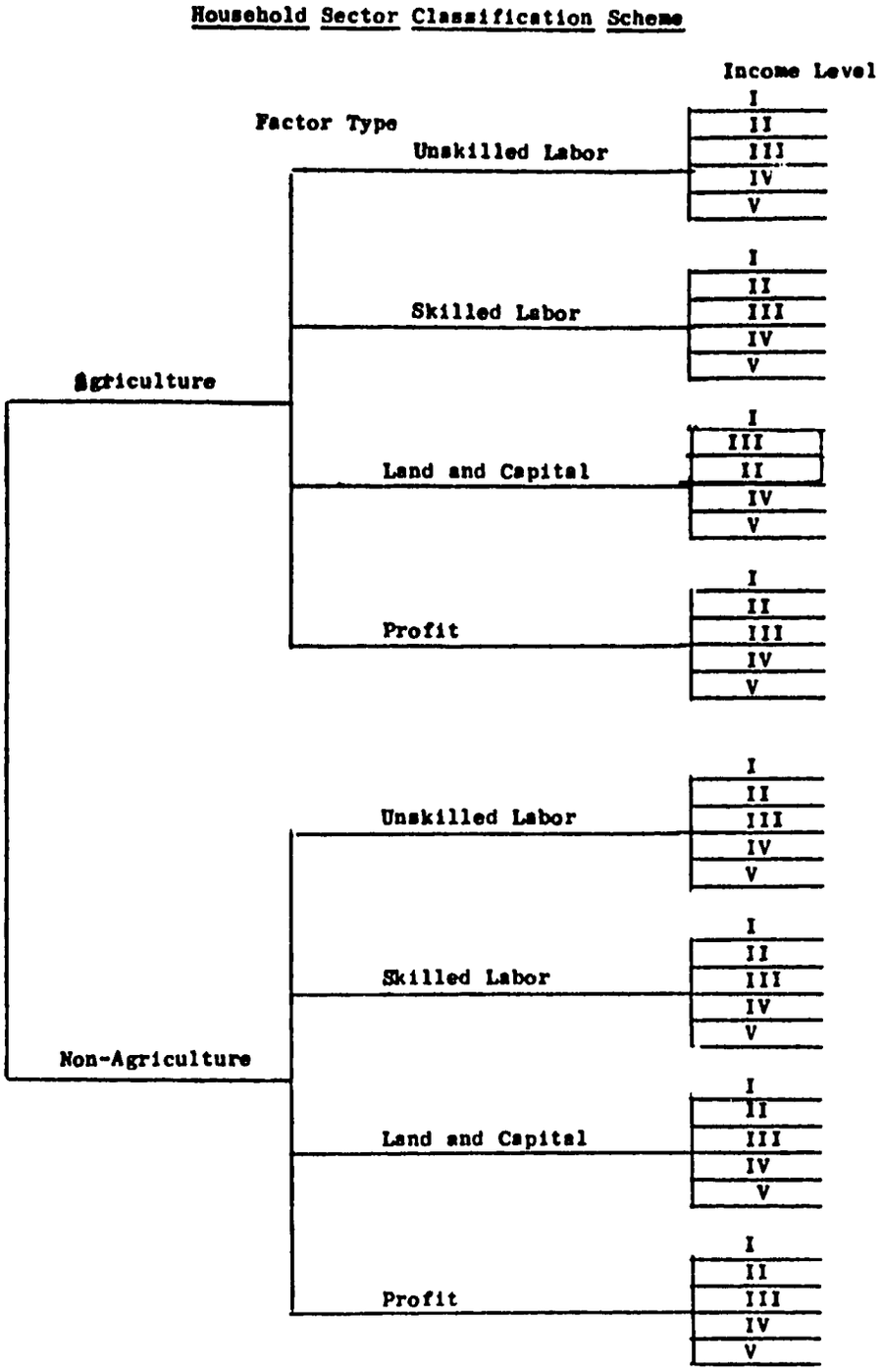
Household Sector Classification Scheme
Income Level
Factor Type
Unskilled Labor
Skilled Labor
Land and Capital
Profit
Agriculture
Non-Agriculture
I
II
III
IV
V

Figure 3.

A FARM MODEL WITH ENDOGENOUS CONSUMPTION ACTIVITIES FOR THE DOMINICAN REPUBLIC

This model [4, 1975] treats the farm as a completely interdependent consumption-production unit.

It is assumed that:

a. Production and/or purchase of food to fulfill certain minimum nutritional requirements is of fundamental importance to the farm household,

b. The family has preferences concerning the make-up of its diet, but is indifferent to the source of a specific food (purchased or home produced)

c. Short term credit is available for purchase of food and farm inputs,

d. Over the length of a harvest period, the farm family decides how to allocate its physical and financial resources to satisfy its nutrient intake needs,

e. Given these considerations the family seeks to maximize expected returns from production activities.

The programming formulation links a small farm production model with a least cost diet model via a distributional matrix. Cropping activities include beans, rice, corn, yuca, plantains, peanuts, tomatoes, and onions and food purchasing activities include beans, rice, yuca, plantains, fruits and vegetables, milk and eggs, meat, bread and oil. Two production activities are included for each crop (one at a traditional technology

level and one at a mid-level one. Intercropping activities are allowed.

Monthly storage and home food consumption activities (with a two percent monthly loss factor due to spoilage) are included for all crops except onions and tomatoes which can only be eaten in the harvest months. Selling activities for each crop are included for the month of harvest only except plantains which can be sold each month. Family labor activities by average number of hours worked daily are included.

The objective function is:

$$\text{Max:} \quad ER = \sum_{i}\sum_{t}(p_i v_{it} - c_{it} l_{it} + .8 d_i s_{i5} - rb_{t-1})$$

where

ER = expected return

l_i = vector of i crop activities in land units

p_i = farm price vector

d_i = retail price vector

v_i = sales vector

c_i = variable costs per land unit vector

s_i = stored surplus vector

r = interest rate

b = borrowed funds

The t indexes refer to monthly time periods ($t = 1,\ldots.4$) and the i indexes to crop activities ($i=1,\ldots.17$). Expected return is defined here as the sum of the value of market sales in the four month period minus the variable costs of production minus interest charges plus

the stored surplus held over for the fifth month valued at eight-tenths of its retail price.

The resource constraints define limits for land, irrigated land and family labor at the farm level.

$$\sum_i l_{it} \leq L_t \tag{2}$$

$$\sum_i l_{wt} \leq IL_t \tag{3}$$

$$\sum n_{it} l_{it} \leq N_{ty} \tag{4}$$

where L = Land availability,

IL = Irrigated land availability,

N_y = Family labor availability of intensity y,

n_i = Monthly labor requirement in man-hours.land unit.

The index w refers to irrigated crops and y to the intensity classification of family labor. The three intensity categories are: light (0-4 hours per day); medium (5-6 hours per day); and heavy (7-8 hours per day).

The financial constraints are of the form:

$$a_{t-1} - a_t + b_t - (1 + r)b_{t-1} + \sum_i (p_i v_{it} - c_{it} l_{it}) - \sum_j d_j f_{jt} = 0$$

where: a = cash assets,

b = borrowed cash,

d_j = the vector of retail prices of purchased food,

f_j = the vector of foods for purchase.

The index j refers to food purchasing activities (j = 1, ..., 10). These constraints require that the family balance its

cashflows monthly covering production and food costs either by taking out short term loans or selling produced crops. All debts must be repaid in the fourth month; therefore, the borrowing (b_4) variable drops out of the fourth equation.

The distribution equations allow harvested production and stored production to be distributed monthly between sales, storage, and consumption.

$$q_{it}l_{it} + 0.98s_{it} - lv_{it} - s_{it} - e_{it} \geq 0 \qquad (6)$$

where

e_i = vector of home produced foods used for consumption

s_i = vector of home produced foods with held for home consumption

Nutrition constraints for calories, proteins, and vitamin C (as a proxy for other vitamins) require family intake to be above recommended allowances. The calorie requirement is increased marginally according to the number of hours and intensity of family labor.

$$\sum_i k_i e_{it} + \sum_j k_j f_{jt} \geq K_t + g\, n_{yt} \qquad (7)$$

where

k = calories per unit of home produced or purchased food

g = additional calories required by an extra hour of work at intensity y.

K = recommended monthly intake of calories

the other nutrition constraints are of the same form but without the labor term.

The preference restraints require a certain proportion

of beans to rice and oil to starchy foods. Maximum limits are set on the consumption of sugar and peanuts.

The model may be generalized to the regional or sector level by making aggregation assumptions and adjusting constraints.

A SIMULATION MODEL FOR A VILLAGE IN INDIA

One means of studying the relative effects of variables operational in development processes at the micro-level is to look at a small unit in an agrarian society as a socioeconomic system (see Dommen [4, 1974]). The components of the system have undergone change over time, and these can be observed. Building from this, it is possible to reproduce the evolution of the system as a whole using a simulation model.

In the example of the study considered here, a village in the Indian state of Punjab was chosen as the unit of observation. It was felt that in Indian conditions the village could be considered as a meaningful unit since many of the activities of the villagers are done on a village-wide basis and there is a feeling of unity among those inside the village vis-a-vis those on the outside. Furthermore, the village incorporates within itself many of the features of the wider economy such as wealth and income disparities, imperfect factor markets, class structures, and differential power relationships. The village was studied over the period 1911-1974, using mainly published data.

The first step was to trace the time pattern of the component variables. Data were compiled and graphed on such variables as population, infant mortality, fertility, education, home comsumption of foodgrains, marketings of foodgrains, use of agricultural

inputs, input and output price relationships, changes in agricultural technology, etc. Next, these components were studied in groups of two or more to see how they might be related to one another, using both theoretical knowledge derived from previous empirical studies and observation of the plotted time trends. Once cause and effect and suitable time lags has been postulated, a model was elaborated. Then, using a simulation program, the component variables were given their actual values and time trends in the village were simulated over the span of years under study. The objective in this phase was to bring the behavior of the model into as close a match with the actual behavior of the system as possible. Following the achievement of the "basic run" of the model, the final step was to apply measured changes of initial values to variables in the system and to measure the consequent changes produced in the system as a whole in repeated runs of the model. This procedure was thought to give an idea of the relative importance of different components in determining the path of change.

The model consisted of "levels" and "rates" (see Figure 4). The two most important "level" variables were Marketed Surplus of the Community and Median Level of Living of the Community. Both were measured in terms of grain equivalents, following the precedent of Hsiao-tung Fei's studies of peasantry in prewar China. In the model, Median Level of Living of the Community is a subjective approximation of all the variables that make up the actual level of living of the farm families in the Indian village, including measures of their assets and income, their ability to

nourish, clothe and house themselves, their state of health, their ability to educate their children, and their ability to survive disaster. The variable Median Level of Living of the Community in the model was a function of two other variables, the Desired Minimum Subsistence Standard of Living (the standard the family tries to stay above), and the Desired Achievement Standard of Living, (the standard the family seeks to attain), Values of the Median Level of Living of the Community lie between those of these two variables.

The model was used to test a number of hypotheses. Among the significant findings were the following: (1) the higher is producers' evaluation of the risk involved in using a particular available technology, the slower is the adoption of this technology and therefore, the slower the growth rate of the marketed surplus; (2) there exists an inverse relationship between the median dependency ratio of the community and the growth rate of the marketed surplus (thus, a high dependency ratio depresses the level of living); (3) an advance in primary school education contributes significantly to the well-being of the community both through the level of living calculus and the marketed surplus; and (4) a movement in relative prices in the direction of greater profitability of production accelerates the growth rate of the marketed surplus even in the absence of technological change, and it may itself bring about the adoption of new technology.

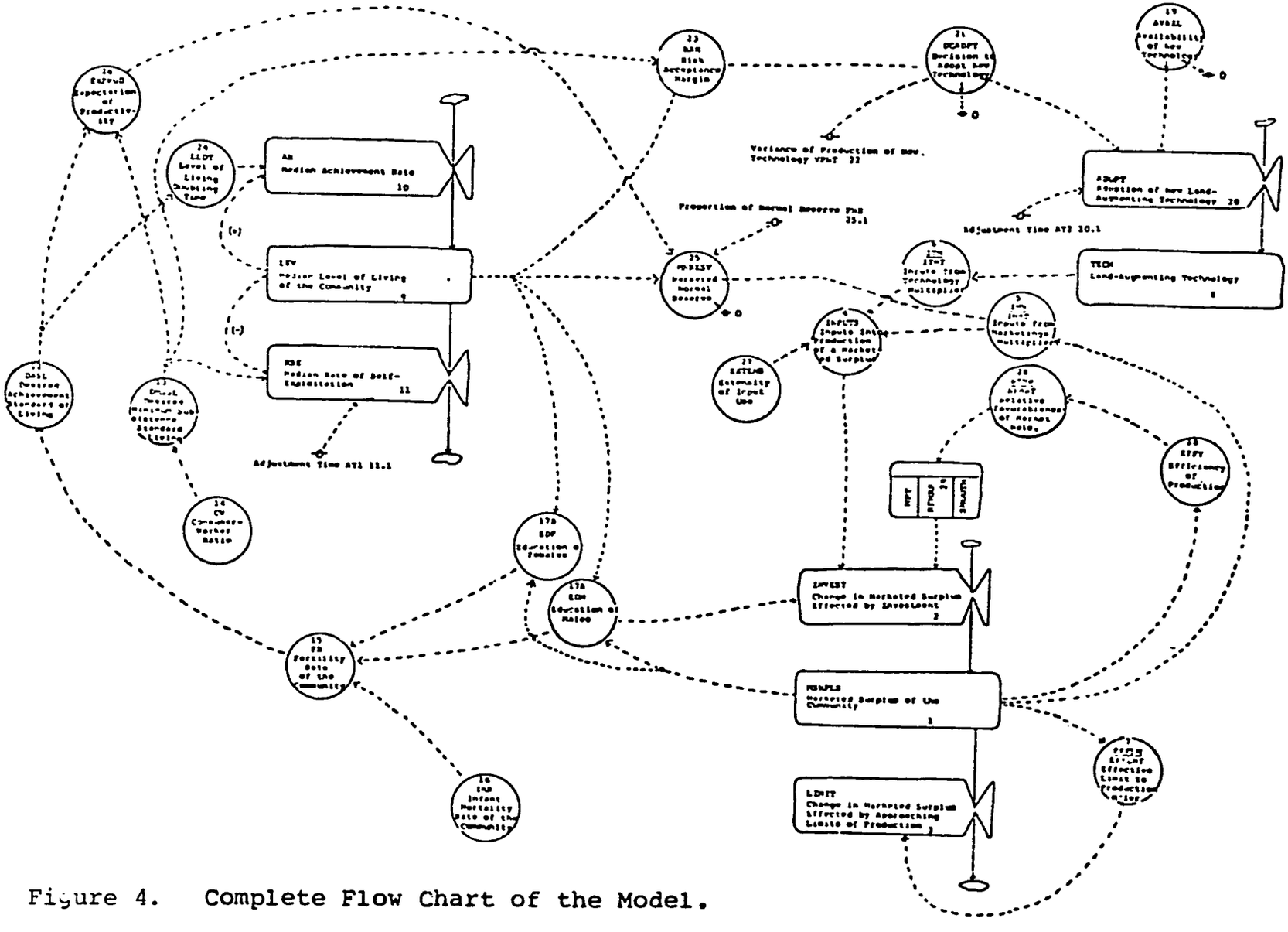

Figure 4. Complete Flow Chart of the Model.

A RECURSIVE PROGRAMMING MODEL FOR THE PUNJAB

The principal assumptions concerning farmers' decision making in this model formulated by I. J. Singh [20, 1973] are:

a. Farmers first determine subsistence needs;

b. Their willingness to adopt new practices is related to exposure and can be predicted by current production involving the new practice;

c. Farmers limit investments in capital goods according to a flexible accelerator type of bound;

d. Farmers attempt to distribute risk by choosing a portfolio of crops; changes are limited by "rule of thumb" percentages;

e. Anticipated prices are based on recent market experience;

f. Given these considerations, farmers allocate their resources to maximize net anticipated cash returns from farming;

The model can be succintly summarized by the following system of equations:

$$\text{Max } P(t) = \sum_j a_j X_j \tag{1}$$

subject to

$$\sum b_{ij} X_j \leq C_i(t) \tag{2}$$

where

$$C_i(t) = g_i(X_j^* (t-1), C_i(t-1), Z(t)) \tag{3}$$

$$j = 1,\ldots n,\ i = 1,\ldots, m,\ t = 1,\ldots \theta.$$

X(t) is a vector of farm-household activities that includes production (land preparation, planting, cultivating, fertilizing, harvesting, processing and transportation of final and intermediate outputs of field crops in two cropping seasons); purchase(of variable inputs such as fuel, fertilizers, hired labor, improved seeds, concentrates and government controlled canal water); sales (of final outputs after harvest); financial (saving, borrowing and debt repayment); investment (land improvement and purchase of capital goods such as tractors, tubewells, threshers, harvesters and cane crushers) and household (subsistence consumption of food and fodder, commercial consumption and labor supplying on and off farms) activities.

Equation (1) measures the net cash returns to fixed farm resources for each year (sales minus purchased inputs, net interest payments and an investment charge on a straight line depreciation basis). It is maximized on period after period with certain parameters depending on the solution of the previous period.

Choice activity levels are constrained by resource, subsistence and behavioral limitations (2) at the regional level for each crop year.

Resource constraints include limits on:

1. family and wage labor;
2. non-farm purchased inputs;
3. animal draft and machine capacities;
4. irrigable, rain-fed and canal irrigable land for two cropping seasons.

Financial constraints include:

1. working capital availability;

2. amounts of short term borrowing at various interest rates

Subsistence constraints are:

1. farm outputs expressed as lower bounds on the amount required for household consumption and maintenance;

2. amount of fodder required for maintaining and using draft animals.

Behavior constraints are:

1. crop flexibility constraints that place lower and upper bounds on individual crop acreages in any given year

2. adoption constraints that place upper bounds on the adoption of new technologies or crop varieties over time.

The inclusion of feedback functions (3) "outside" the optimizing model is what links the problem from one year to the next. These depend on the vector of past solutions $X^*(t-1)$ previous constraint levels $C_i(t-1)$ and exogenously given data $Z(t)$.

The elements of these feedback functions are:

1. adaptive flexibility and adoption and adjustment constraints;

2. machine and power capacity constraints (dependent on past investment);

3. cash availability (from last year's sales);

4. credit limits (dependent on past borrowing and repayment activities);

5. availability of regional land, labor and draft resources (dependent on exogeneous data).

NOTES ON PRODUCTION FUNCTIONS AND THEIR USE

The production function relates inputs to outputs. The idea of a function to define the production process is attributed to the 19th century economist P. H. Wicksteed.

The production function $X = f(v_1, v_2, \ldots v_n)$ (1) is a single-product function and relates the n inputs, v_i, to output, X, in such a manner that X represents the maximum output technically obtainable from the quantities of the v_i. Note that the inputs may be defined as services as well as hard goods.

In the theoretical application of production functions, the following four assumptions are usually made:

1. Inputs and outputs are measurable;
2. Inputs and outputs are measured per unit time;
3. Inputs and outputs are non-negative;
4. Inputs and outputs are homogeneous in their nature.

The second of these assumptions is particularly important as concerns agriculture since it is obvious that where a double-cropping system prevails doubling the quantities of labor, capital and other nonland inputs should double the output relative to single-cropped land, whereas doubling these same inputs where a single-cropping system prevails should not double the output. The effect of double-cropping is the same as that of bringing more land into production. The Classical economists used the language logically in talking of the intensive margin of cultivation as being that of applying additional nonland inputs to the same land and of the extensive margin of cultivation as being that of bringing additional land into cultivation; modern practice has, unfortunately

for clarity's sake, confused the concepts of intensity and extensity of input use by referring to double-cropping as "more intensive" cultivation, wereas the input of labor, capital, etc. per acre per crop may remain unchanged.

Inputs may be specified, for purposes of theoretical application of production functions, in terms either of quantities available or quantities utilized; consistency should be observed, however.

If in the single-product, two-input case the production function is imagined to be a three-dimensional surface governed by the two horizontal axes along which the quantities of inputs are measured and a vertical axis along which output is measured, a vertical section through this surfact parallel to the horizontal axis v_1 yields the two-dimensional Total Product Curve which shows output to be a function of v_1, the quantity of input v_2 being held constant. From this Total Product Curve, the Average Product Curve and the Marginal Product Curve of v_1 can be derived.

A horizontal section through the production surface, on the other hand, yields an Isoquant, a locus of points at which different relative quantities of inputs v_2 and v_1 yield a constant output.

Finally, a vertical section through the production surface passing through the origin yields an Isocline, the projection of which onto the v_1/v_2 plane yields a Scale Line, the locus of points at which proportional increases in inputs yield proportional increases in outputs.

The Cobb-Douglas formulation is the preferred form of the production function for empirical applications due to its ease of calculation. The usual representation is:

$$X = a_0 \, v_1^{a_1} \cdot v_2^{a_2} \qquad (2)$$

where X is some output and v_1 and v_2 are the inputs; a_1 and a_2 are the estimated production elasticities of the inputs; and the function is homogeneous of degree $a_1 + a_2$.

Given (2) a change in technology would generally be represented by a change in the parameter a (which can be estimated for a sample of farms by ordinary least squares regression analysis). Such a change would shift the function upward leaving production elasticities unchanged.

The Cobb-Douglas function may also allow for observed variations in techniques of production or some other factor that is believed to influence the input-output relationship without itself constituting a separate factor of production. Let us call such a factor "h"; it may be fertility of land, education of the operator, or capital intensity of production measured by some index of total value of capital investment per acre for each farm, etc.

In this case, we can rewrite (2) as follows:

$$X = a_0 \, v_1^{a_1 h} \cdot v_2^{a_2 h} \qquad (3)$$

The products $a_1 h$ and $a_2 h$ represent the elasticities of production of the factors of production, just as in the simple formulation. Since v_1, v_2, and h are all observed quantities, the parameters a_0, a_1, and a_2 can be estimated by OLS, first transforming (3) into logarithmic form.

Empirical studies using such a modified C-D production function have shown (1) that the coefficients are statistically significant; (2) that the elasticities of production of the factors vary systematically across the range of values of "h"; and (3) that the returns to scale also vary systematically. This has permitted more accurate estimation of the efficiency of resource utilization by farms.

The principal uses to which the Cobb-Douglas production function have been put are:

1. to estimate the efficiency of resource utilization, in the technical sense of comparing the quantities of inputs used to produce a quantity of output (if sufficient care is taken to include all output in the equation, it can be shown that "subsistence" farmers use their resources in an efficient way).

2. to estimate the price efficiency of resource use (this is a more difficult calculation to make because it involves imputing values to unpriced inputs and outputs).

One of the features that makes the C-D production function attractive for calculations is that it is linear in logs. The main difficulty in using the production function in empirical investigation, however, stems from the fact that it assumes maximum production for given inputs, whereas the production we observe is always less than maximum, due to differences in entrepreneurship (an omitted input), weather and other chance factors, and lack of definite knowledge about the objective function the farmer follows. In connection with this last point, profit maximization and cost minimization for given output are convenient assumptions. Statistically, there is a trade-off between aggregation error and multicollinearity. As the researcher specifies more separate inputs, he reduces the one while increasing the other.

Because of the easily manageable form of equation (2), the cost function can be derived directly from the production function by substituting the marginal productivity conditions for competitive equilibrium into (2), yielding:

$$C = c_2\left(\frac{a_1 + a_2}{a_2}\right) \cdot \left[\left(\frac{a_2 \cdot c_1}{a_1 \cdot c_2}\right)^{a_1} \cdot \frac{X}{a_0}\right]^{\left(\frac{1}{a_1 + a_2}\right)} \tag{4}$$

where C is the total cost, c_1 is the price of v_1 and c_2 is the price of v_2. Then, by equating marginal cost to P, the price of output, and rearranging one can derive the supply function for output X:

$$X = a_0^{\left(\frac{1}{1 - a_1 - a_2}\right)} \left(\frac{a_1}{c_1}\right)^{\left(\frac{a_1}{1 - a_1 - a_2}\right)} \left(\frac{a_2}{c_2}\right)^{\left(\frac{a_2}{1 - a_1 - a_2}\right)} P^{\left(\frac{a_1 + a_2}{1 - a_1 - a_2}\right)} \tag{5}$$

If $(a_1 + a_2) = 1$, the cost is proportional to output and the supply curve is infinitely elastic (i.e., horizontal).

It is readily seen that direct empirical estimation of supply functions is seriously inhibited by what is called the 'identification problem'. The data on price and quantity do not specifically describe supply relationships, but they are equilibrating values of supply and demand. Indirect approximations can be made by simultaneous estimation of supply and demand relationships.

The statistical formulation which has had the most success in estimating supply response has been the Nerlovian distributed

lag model which makes planned supply a function of expected prices, and is of the general form:

$$P_t^* = B_2 + a\ (P_t - P_{t-1}) + P_{t-1} \qquad (6)$$

where expected price is equal to price in the previous period corrected by a constant B_2 and the coefficient a multiplied by the change in market price. The model can be modified to take into consideration deviations in yield and geometrically weighted lag terms can be included. Irreversible supply functions can be estimated for permanent or tree crops by fitting Nerlovian lag functions with supply shifts permitted through dummy variables. If the assumption of perfectly competitive markets is dropped and elasticities of supply of factors of production introduced, non-competitive cost functions can be generated.

The main reason the theory of production is of only limited use in analyzing production relations in the LDC's is due to the existence of imperfect markets in all economic relations which "subsistence" farmers face, and not due to the simplifying assumptions attached to the use of the Cobb-Douglas or other production functions. The estimation of relative technical efficiency of production is on a fairly firm footing, compared to the estimation of price efficiency.

NOTES ON THE FAO COMMODITY DEMAND PROJECTIONS

Trend oriented projections are made independently for world-wide production and demand for agricultural commodities by the UN Food and Agriculture Organization [3, 1971]. Though the projections are made without consideration of adjustments to either the quantity demanded or produced required to maintain world equilibrium, analyses based on such projections can identify major problem commodities and indicate intensity of world market pressure for individual commodities which may call for changes in prices and policies.

Methodology of the demand projections will be considered here. It is assumed that relative prices of agricultural commodities will remain constant, there will be no change in agricultural policies, population will increase according to the UN "median variant" and GDP and PCE (Private Consumption Expenditure) will grow according to past trends except in those cases where recent events aimed at changing these trends have occured.

The first step of the projection is the formulation of production/utilization accounts by country on the physical stocks and flows of agriculture.

The supply elements comprise:

a) the stocks of specific commodity available at the beginning of the reference period (opening stocks);

b) the production of the commodity (or output for a processed commodity) during the reference period;

c) imports of the commodity, covering all movements into the country irrespective of purpose

The utilization elements comprise:

a) exports of the commodity during the reference period;

b) quantities used as feed;

c) quantities used as seed;

d) quantities lost through wastage at all stages between farm and retail level (but not including waste beyond the retail stage);

e) quantities used for processing into other commodities

f) consumption as human food, directly or processed;

g) utilization for non-food purposes (direct or processed);

h) stocks available at the end of the reference period.

From these accounts, detailed food balance sheets are constructed by applying conversion factors, extraction rates and nutrient content data to supplies available for human consumption. Population is taken to be total de facto population at the mid-point of the reference period with attention given to special groups such as temporary migrants, tourists, etc.

Consumption functions are then estimated from family budget surveys, time series and intercountry comparisons, and the income elasticity derived by taking the logarithmic derivative of the estimated function. Table I includes the functions most frequently used.

TABLE I

	Function: Original	Function: Transformed	Marginal propensity to consume	Coefficient of elasticity
1. Double-logarithmic	$y = e^a x^b$	$\log y = a + b \log x$	$b \frac{y}{x}$	b
2. Semi-logarithmic	$e^y = e^a x^b$	$y = a + b \log x$	$\frac{b}{x}$	$\frac{b}{y} = \frac{b}{a + b \log x}$
3. Log-inverse (sigmoid)	$y = e^{a - \frac{b}{x}}$	$\log y = a - \frac{b}{x}$	$b \frac{y}{x^2}$	$\frac{b}{x}$
4. Log-log-inverse	$y = e^{a - \frac{b}{x}} x^{-c}$	$\log y = a - \frac{b}{x} - c \log x$	$\frac{y(b - cx)}{x^2}$	$\frac{b}{x} - c$

Note: The above equations express the relationships between per capita consumption (y) and per capita income (x). Logarithms are in natural basis. If decimal logarithms were to be used a correction factor would be necessary. Thus, the elasticity coefficient may be written: $0.4343 \frac{b}{y}$ for function 2., and $2.3026 \frac{b}{y}$ for function 3.

These four types; viz., log-log, semi-log, log-inverse and log-log-inverse are fitted to available data from household budget surveys using least square regressions weighted by the number of households in each group. Households are stratified where possible into homogeneous groups according to socio-economic factors such as household size, occupation, urban and rural population. Covariance analysis is then applied to isolate the effect of income from these other factors.

This information is systematically compared with regression analysis done on available time series data or per capita consumption and intercountry comparisons of per capita consumption.

Per capita demand by commodity is projected on the basis of the equations of Table II. The first three types of functions used (log-log, semi-log, and log-inverse) are fully determined by the value of per capita consumption and per capita income at the base period and the value of the income elasticity at this

point. The fourth function (log-log-inverse) contains an additional parameter which can be determined either by the income level X_m corresponding to the maximum level of per capita consumption Y_m , or by the value of this maximum level of consumption (Y_m). Nutritive content ratios are then applied to commodity projections to derive the projected food balance sheets.

TABLE II

Functions Used for the Calculation of Increase in per capita Demand

	Demand functions	Increase in per caput demand*
1. Double-logarithmic	$\log_e y = a + b \log_e x + zt$	$\log \frac{y^1}{y_0} = \eta_0 \log \frac{x^1}{x_0} + 0.4343\ z(t_1 - t_0)$
2. Semi-logarithmic	$y = a + b \log_e x + zt$	$\frac{y^1}{y_0} = 2.3026\ \eta_0 \log \frac{x^1}{x_0} + z(t_1 - t_0) + 1$
3. Log-inverse	$\log_e Y = a - \frac{b}{x} + zt$	$\log \frac{y^1}{y_0} = 0.4343\ \eta_0 \left(1 - \frac{x_0}{x_1}\right) + 0.4343\ z(t_1 - t_0)$
4. Log-log-inverse	$\log_e y = a - \frac{b}{x} - c \log_e x + zt$	$\log \frac{y^1}{y_0} = \frac{\eta_0}{1 - \frac{x_0}{x_M}} \left[0.4343\left(1 - \frac{x_0}{x_1}\right) - \frac{x_0}{x_M} \log \frac{x_1}{x_0}\right] + 0.4343\ z(t_1 - t_0)$

Note: x_0, y_0, t_0, $_0$ refer respectively to per capita Private Consumption Expenditure, per capita consumption, time and elasticity coefficient at the base period; x_1, y_1, t_1 refer to the corresponding values at the end of the projected period. In function (4) there is an additional parameter, which is represented by x_M, corresponding to the value of Private Consumption Expenditure, for which the maximum level of consumption is reached. Formulas are expresded in decimal logarithms.

Nutritional consistency checks are made with available data manually by trial and error with a nutritionist. Due to the

possibility of substitution between different food items in a country's diet, the margin of error of the projections generally increases with the level of disaggregation in the food groups. Apart from the usual nutritive values four ratios are used to make judgements on the consistency of the food balance estimates. They are:

a. Calories derived from carbohydrates as a percentage of total calorie intake;

b. Calories derived from proteins as a percentage of total calories;

c. Percentage of animal proteins as a function of total proteins;

d. Calories derived from fats as a percentage of total calories.

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