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GLOBAL MODELING OF FOOD AND AGRICULTURE:

BACKGROUND TO A POSSIBLE APPROACH

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GLOBAL MODELING OF FOOD AND AGRICULTURE:

BACKGROUND TO A POSSIBLE APPROACH*

by

George E. Rossmiller, Glenn L. Johnson and Martin E. Hanratty**

Since the Club of Rome reports, The Limits to Growth,[1] and Mankind at the Turning Point,[2] were published, interest and activity in global modeling has rapidly increased. These reports were directed at a mass audience and were intended primarily to shock the reader into recognition that major changes are necessary in the various world political, social, economic and technical systems if disaster is to be averted. While the reports have served a useful purpose in highlighting a number of the major issues of immediate concern to mankind, it is now time to disaggregate and deal with each in much more detail.

A detailed analysis of these issues is, at present, hampered by the lack of an institutionalized analytical capacity at the international

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[1]Donella H. Meadows, et al., The Limits to Growth, (New York: University Books, 1972).

[2]Mihajlo Mesarovic and Edward Pestel, Mankind at the Turning Point: The Second Report to the Club of Rome, (New York: E. P. Dutton and Co., Inc., 1974).

level. Such a capacity requires a stable core of professionals capable of amassing, assimilating and analyzing data and information within a problematic framework. Providing a backstop for such a core would require the creation of a centrally located worldwide data bank and generalized computer software library capable of supplying both up-to-date information and analytical models which would be used to provide national and international policy makers with an understanding of the likely consequences of alternative courses of action to solve specific problems involving food and agriculture.

The retarded development of such a multi-purpose capacity can be linked to the absence of a world governing body directly responsible for analyzing and implementing programs which address global issues. The creation of such a capacity in the absence of a world governing body will be difficult because of the importance of extensive interactions encompassing professionals and policy makers in the contexts of specific problems. To date the opportunities for engaging in such interaction are at the national level or with international agencies at the national level. The following paper examines one such domain, the world food-population issue, as an initial step in developing a much broader world analytical capacity.

Why An Analytical Capacity is Needed to Examine the World Food and Agriculture Dimension of World Problems

The need for an analytical capacity addressing topics of relevance and use to decision makers for planning and policy formulation has never been greater. Rapid changes in inflation and rising food prices, increasing populations and income distribution are continually posing problems which must be confronted by today's decision makers. Identifiable problems exist when a public or private decision maker, with power to act within the constraints of his decision-making structure, finds that a situation is less good or more bad than is desirable and necessary. When viewed in this perspective, it becomes apparent that a large number of specific problems with agriculture, food, population, and nutrition dimensions are before public and private decision makers. These problems are interrelated in a socio-economic, political, humanistic and technical web within and among nations. It follows that no single academic discipline or model, however complex, can deal adequately with the full range of problems which can be specified. What is needed is a variety of generalized models which will analyze the complex set of relationships surrounding the food and population situation and a capacity to update and develop new models as new problems arise.[3]

The need to build models of processes involving agriculture, food, population and nutrition arises from the problems with these dimensions which originate in and are solvable by real-world market and nonmarket changes. Market forces are continually changing due to changes in population, income distribution, tastes and preferences, weather, technology and other demand and supply conditions. Nonmarket changes arise from changes in human capacity, outlook and perspectives, institutions, technologies, and patterns of public concern. Changes lead to problems of resource allocation, income distribution, and resource ownership. Solutions to these problems have a multitude of socio-economic, political and human consequences which the decision maker must weigh in his choice of a solution. Often, particularly when extra market choices are made, decisions will allocate benefit to some at the expense of others. Such allocations

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[3]A general discussion of the systems that make up or embrace agriculture can be found in African Agricultural Research Capabilities published by the National Academy of Sciences (Washington, 1974).

usually require enforcement to maintain. Selection of the enforcement strategy which may include aid and charity, political action, threats or even military action is as much a part of solving these extra-market problems as the initial process of identifying actions to solve them.

The need for problem-solving analysis and thus models in the international arena has increased as nations have become more interdependent and as population, per capita incomes, and the demand for food has increased. The comparative advantages of the productive land, labor and capital in different countries has made international trade desirable and, indeed, necessary, especially in food. Some of the problems associated with food, however, cannot be handled by the free flow of forces in the international market. Increasing national populations and the growing use of nonmarket mechanisms in the allocation and distribution of food provide stark evidence of the growing concern which decision makers in the excess as well as deficit food producing nations are placing on food and population. The need for modeling and analysis to design improved processes for pricing, distributing, storing and managing reserves is growing and can no longer be ignored.

The urgency of the work has become increasingly evident. Events of the early 1970s, including the faltering of the green revolution, adverse weather over major areas of the globe, the U. S. decision to drastically reduce grain stocks, the abrupt change in Russian grain import policy, and major disruptions in the world petroleum and financial markets combined to endanger the tenuous margin of safety which existed in the world food-population balance. These events have led to drastic increases in the costs of agricultural inputs--primarily fuel and fertilizer, short supplies of food commodities, sky-rocketing agricultural prices, volatile commodity markets on a world scale and an inability of the poor countries to pay for the larger amounts of food, petroleum and modernizing inputs they desire from world markets.

The press of rapidly increasing populations on the agricultural resource base is also recognized as an important dimension to many problems. In 1974 two major international conferences were held concerning these issues. The first was the World Population Conference. A major question arising from this conference was whether population control and declining rates of population growth are a prerequisite to or a result of economic and social development. Even though little empirical evidence exists to support either position, most delegates chose to accept the hypothesis that declining rates of population growth are a result of development and called for increased efforts on the part of developed nations to support LDC development. In addition, the conference adopted the proposition that family planning and information services should be available to all people as a human right. Many countries, however, are unwilling to act. The second conference was the World Food Conference in Rome which recommended a worldwide food intelligence network in which countries would provide data and information on short-term outlook of food production and stocks. Such a network would provide an early warning system to pinpoint impending local food stock shortfalls to allow time to avert localized disasters through food allocations from a proposed world food stockpile.

Thus, the events of the early 1970s and the two major world conferences stress the need for better information and analysis of world food production potentials, population control possibilities, and their interactions.

To a significant extent, the aggregation of individual national policies relating to population and food will determine the relative rates of change, the levels, and the regional disparities which will exist among these variables in the future.

The modeling and analytical capacity called for below can provide additional information about these variables in the short (1-5 year) and intermediate (5-20 year) range. It would be valuable to both national and international decision makers in organizations such as the U. N., FAO, World Bank, the Regional Investment Banks, as well as bilateral donor agencies such as AID. In most cases the modeling capacity would not provide national decision makers with detailed information concerning the domestic consequences of policies and planning done within their nation. It could, however, provide information on the external effect of individual national policies to both the national decision maker and others in the international community.

Past and Ongoing Modeling Efforts

Several food and agricultural modeling efforts are now underway through FAO, World Bank, USAID and under individual country auspices. Most focus on the domestic consequences of national policies and planning. While they are important and valuable for policy analysis within nations and provide the basis for limited conclusions concerning the external effects of domestic policy, they fall considerably short in providing basic external information for analyzing the interdependent effects of national policies between nations in the needed global perspective.

At the other end of the modeling spectrum are the efforts characterized by the two Club of Rome reports. Due to the complexity of each of the major issues confronted in these models, to say nothing of the complexity of their interactions, these two modeling efforts were kept at a global or regional level without national detail. This level of analysis however has serious drawbacks. Problems posed at such levels are not within the domain of influence of any existing policy decision-making body. Thus, there is no regional or world government capable of developing policy and planning directions needed to confront the problems as enumerated in the reports.

Several important lessons can be drawn from these modeling efforts. First, to be of operational use, a global model of food and agriculture must necessarily be aggregated from specific national level components capable of assessing the internal and external consequences of national planning and policy efforts. To build operationally relevant models, analysts must interact with decision makers who have the authority and responsibility to formulate and carry out policies and programs which affect the values of the major variables of concern. Continuous interaction during the model-building process is required so that the knowledge of legislators and government officials can be combined with the skills of the model builders and analysts. At the world level, analysts have no effective legislative or executive world bodies with which to interact. Even the FAO analyst is deprived of the opportunity to interact with a world government having responsibility for implementing solutions to problems involving agriculture, food, population and nutrition.

Second, at least in the first round, a model of food and agriculture should not attempt to address in-depth interrelationships with the environment, energy, industrialization and other major areas. Rather, the focus should be on food and agriculture with the model structure being formulated to allow for future linkages with detailed models of these other areas as resources become available and as theory and new knowledge are developed. It is imperative to project the effects of changes in energy, the environment, the natural resource base and population. The initial conceptualization of the model should introduce these changes as exogenous variables or shocks to the food and agriculture sector.

Third, while a global model which simulates a scenario over a future time span of 100 to 200 years is useful to draw attention to the major issues and gross interrelationships involved, it does not address the consequences of short-term policy adjustments which may be required in various parts of the system. To accomplish this goal a time span ranging up to 20 years is more realistic.

Fourth, the model structure should be able to deal with national and regional differences in the distribution of productive capacity and populations. In a heterogeneous world shortfalls of food, while numerous, are small and perhaps randomly distributed through space and time. Consequently, malnutrition, starvation, disease, war and social unrest occur more or less continuously. The continuous adjustment of population to changes in productive capacity and food supplies occurs in the absence of catastrophic famines and social upheavals.

By contrast a highly homogeneous world would be characterized by a small number of very large scale famines, pestilences, social upheavals and major wars. Population adjustments in a world characterized by these major shifts in productive capacity and food supply would be made up of large disasters occurring at single points in time over wide geographic areas unless a world social or governmental control system maintained the required population-food balance. Fostering equity considerations might be another function of a government. It is extremely important in developing a model of world food and agriculture that the interrelationships among heterogeneity and homogeneity, social and governmental control mechanisms and the biological control methods be considered in the context of either a growing or deteriorating capacity to produce food.

Fifth, when food and population are viewed as aspects of a larger set of problems, it is apparent that specific models or model modifications are needed for each problem.

Sixth, it is clear that <u>general</u> models are needed. The word general, however, has a variety of meanings. When used as an adjective modifying <u>approach</u>, it means that the approach is unrestricted with respect to: (a) types and sources of information (multi-disciplinary), (b) philosophic orientation (capable of dealing with positive, normative and prescriptive knowledge in the context of a particular problem), and (c) technique (i.e., capable of using nonmaximizing or predictive as well as maximizing or prescriptive models). For example, economists using static optimizing models cannot solve the world grain management problem by themselves. Nor can agronomists solve the food allocation problem with genetic models that continually increase crop yields with high costs and high risk inputs. Instead, both disciplines in conjunction with many others must join their disciplinary theories, methodologies and information into generalized models which encompass the unique domains of the specific problems being addressed.

The word <u>general</u> is also used as an adjective to modify the word <u>model</u>. A general model has a capacity to handle more than one specific problem without major modification. The more modification required in a model in order to transfer it from one problem to another the less general it is. A global model of food and agriculture would have to be general enough to handle a fairly broad class of problems faced by the international and national agencies concerned with solving these problems, without major modification.

Due to the complexities of the issues, the problems which confront decision makers will fall outside the capabilities of the general model to greater and lesser degrees. Thus, in order to be general, a model should be constructed of components which can be disassembled and reassembled to address the domains of specific problems, perhaps in a set. The process of disassembling and reassembling models to represent different domains requires: (1) a software library in which components can be stored and made readily available, (2) a data bank, and above all, (3) a stable of competent system-simulation personnel capable of disassembling and reassembling the components of the models to address specific problems. The team or stable of experts should be disciplinarians with enough command over system-simulation techniques to bring the theories and data of their disciplines to bear on the problem of modeling the domains of specific problems. At times the team would merely reassemble existing components; at other times, it would undoubtedly be necessary for them to develop new components. New components may often be important pieces of social capital which should be placed in the software library and preserved for use by subsequent persons building models of the domains of other specific problems.

Experience has shown that models of the domains of specific problems are useful in finding solutions. The solution sought, be it an individual act, a project, a program or an overall policy, represents, in some sense, the best of the set of open alternatives available for solving the problem. The search for a solution, however, does not mean that optimizing models are to be used initially without regard to the processes of establishing the preconditions for finding the best.[4]

The first such precondition is the acceptance of a common denominator in terms of which the "goods" being sought and "bads" being avoided in solving the problem can be measured. Until such a common denominator is available there is no single objective function to maximize in defining and locating the best. The second precondition--really a special case of the first--is that the common denominator selected must have interpersonal validity. This is necessary if choices are to be made among alternatives which impose damages on some while conferring benefits on others at the same or different points in time and space. The third requires that the alternative actions, projects, programs and policies being considered be placed in the order of their decreasing excess of "good" over "bad" per unit of bad, as measured by the common denominator selected in one and two above. The fourth and possibly the most difficult is the acceptance of a decision-making rule to be employed in choosing among alternatives. If perfect knowledge is assumed, the obvious rule is to subtract bad from good and maximize the difference. Under the assumption of imperfect knowledge a number of rules may be used including minimax techniques, random selection, the maximization of the present value of the expected future net difference between good and bads, etc.

Generalized system simulation models provide arrays of performance variables that can be used to measure the consequences of alternative

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[4]Additional comments concerning the problems associated with establishing the preconditions for selecting the best set of solutions to a problem can be found in Manetsch, et al., A Generalized Simulation Approach to Agricultural Sector Analysis, (East Lansing: Michigan State University, 1971), pp. 17-20 and Rossmiller, et al., Korean Agricultural Sector Analysis and Recommended Development Strategies, 1971-1985, (Seoul: Agricultural Economics Research Institute, East Lansing: Michigan State University, 1972, pp. 32-36.

courses of action. The discussion of these arrays amongst interested parties along with further modeling, often leads to the establishment of the above preconditions for decisions.

After the model has been used iteratively and interactively to help establish these preconditions, it can be modified and placed in an optimization mode to assist in locating solutions to the problem. Such cautious use and development of a model in a problem-solving process is far different than the use of linear programming, econometrics and other models which either maximize or assume maximizing behavior. The premature use of such maximizing models shortcuts the important iterative, interactive process of investigating the problem and generally leads to a creditability gap between researchers and decision makers.

In creating models, two uses should be kept in mind. A model will sometimes be used to represent the phenomena which take place in the domain of the problem under investigation. When operated in this mode, a model is used to reproduce past activity, to describe present activity, and to project future activity under the assumption that a system is not substantially modified. A second use of models is a "design mode." In this case, substantial changes are contemplated in a real-world system containing the domain of the problem under investigation. The objective is one of designing a new system which will solve the problem. With respect to food and agricultural problems, design alterations or modifications include changes in agricultural technology, the institutional structure of the systems including institutions for implementing different decision-making rules and the redistribution of ownership rights and privileges, etc., as well as changes in people themselves through education and incentives to influence their productive capacity, their motivations and their likes and preferences. It is important that global models for food and agriculture be capable of being used in the design mode if the many complex problems involving food and agriculture are to be solved in the decades ahead

Objectives for a Food and Agricultural Global Modeling Capacity

Both short- and long-term problems concerning agriculture are now being considered by such bodies as the World Food Council, FAO and the multilateral and bilateral donor agencies. Their short-term focus centers on where and in what magnitude food supply shortfalls are likely to occur in the next one to five years. The World Food Conference has recommended that an information gathering and early warning system be formulated in conjunction with a world food stock program to assist policy makers in setting market and non-market policy to dampen the effects of these short-term fluctuations. A model of such a food stock program could provide planners and policy makers with answers to a variety of short-term questions such as: (1) what should be the size and composition of a reserve, (2) how should allocations from the reserve be made, (3) where should the reserve be held, (4) should recipients purchase grain from the reserve or should it be given free, (5) who should finance storage and transportation, and (6) should grain be purchased from the international markets or should governments plan for area expansions with the surplus going into reserve.

A set of long-term questions relevant to problems with food and agrarian dimensions deals with the food-population balance over a 5 to 20 year time horizon. These would have to be handled by modified versions of the model. Such versions would have to deal with a wide array of planning, investment and policy variables under the discretionary control of national governments. For example, if 70 percent of the world's population is currently at a subsistence level, what are the tradeoffs between research efforts directed toward controlling population growth versus technological innovation intended to increase food production. A model designed to answer such questions would provide valuable information to decision makers in such areas as the allocation of monies for research and operational programs, the utilization of the international technical research centers (IRRI, CIAT, CIMMYT, IITA, etc.) and the newly established International Food Policy Research Institute. With full recognition of the distinction between the short- and the long-term, a modeling capacity can be developed which will handle both.

In 1964 an eminent British economist, Richard Stone,[5] predicted that by 1984 a computable model of the economy of any country in the world covering the major aspects of economic and social life would be an established part of the machinery of economic activity. In 1974, with ten years still to go, we are capable of building such general models and linking them together on a world scale. However, no single problem-solving model can be built to solve all the world's problems as each specific problem has a more or less unique domain. It is a modeling capacity not _a_ model that is needed. To repeat, this implies components and a stable of problem-oriented systems modelers to interact with decision makers in defining and solving specific problems. The required modeling capacity must be flexible and adaptable enough to reflect the changes in different real-world systems. In addition, it must be adaptable to the different domains of changing problems. When the solution requires

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[5]Richard Stone, "Computer Models of the Economy," Vol. II of _The World in 1984_, ed. Nigel Calder (2 vols.; Baltimore: Penguin Books, 1964), p. 56.

creating a new decision-making unit, the model should be designed to find alternative ways of getting from the present structure to a more desirable future configuration.

With the above in mind, the objectives of developing a general purpose model of food and agriculture as part of an analytical capacity might be as follows:

1) to project the food-population balance position globally and for selected regions and/or countries over a 1-5 year future time horizon,

2) to project the food population balance trends globally and for selected regions and/or countries over a 5-20 year future time horizon,

3) to assess the long- and short-run consequences resulting from the introduction of new alternative sub-systems within the food-population model which focus on specific problem domains,

4) to assess the consequences of alternative national policy options on the existing or a specified global food and agricultural system, and

5) to assess and project the various inputs required by the world agricultural system under the various sets of sub-systems and policies selected above.

A Possible Model Structure

As with any simplified representation of the real world, a general model of food and agriculture must be based on sets of behavioral assumptions. One characteristic which seems to be common amongst all nations is that nations adopt policies concerning food production and utilization which foster their own self-interests. Extending this basic premise to include descriptive information about the values which influence a nation's adoption or rejection of specific policies is one of the tasks which must be done before an optimum set of policies can be designed. Though complete modeling of the linkage among these values and specific national food production, supply and utilization policies is probably impossible, partial modeling is required for the design, eventual adoptic and implementation of policies.

Public policies affect constellations of values through their influence over human actions. In so doing, they play crucial roles both at the national and international level in determining the outcomes of the world food system. The modeling of such a system must allow for the incorporation of a variety of exogenously determined policy variables. The risk and uncertainty associated with policy decisions often make it desirable for the output generated by the model to be probabilistic rather than deterministic. The broad conceptual model presented below attempts to unite the linked structural components which exist in the world food and agriculture system with a number of exogenously determined policy components which affect that system.

To develop the structure of a general model capable of examining problems within the world food-production system, several basic relationships must be examined. Where specific data and knowledge exists, these relationships can be of a causal nature. Where data and information is not available, predictive equations can be used. The initial conceptualization of the system must by necessity rely heavily on the more generalized intuitive and predictive relationships. As design efforts proceed to second and third generation attempts, a conscious effort should be made to isolate the more significant trend relationships within the system and to expand and articulate them in a more causal mode.

The basic relationships which are incorporated in the present conceptualization fall at two levels. At the national level these include the supply and demand conditions surrounding the production and consumption of basic food commodities and a set of accounting identities which define portions of the system structure in which the basic parameters are known. They are designed to measure the structural response of internal surpluses or deficits on internal production and external flows of commodities. At the international level, the components of the system examine the flow of key commodities between countries both commercially and as aid. In addition, a series of international food balance accounts similar to those maintained at the national level monitor world food levels and indicate highly aggregated levels of policy concern. A block diagram depicting such a formulation is presented in Figure 1.

For simplicity, neither the diagram nor the explanatory remarks which follow address the question of regional food balances. The importance of this level of aggregation as attested by the impact of the agricultural policies of the European Common Market cannot be discounted and can easily be incorporated into the present model structure with a minimum of additional effort.

The supply of agricultural commodities at the national level is a function of the food supplies generated internally through present or past domestic production with possible supplementation by commodities imported via commercial purchases and/or food aid. Under normal conditions, the vast majority of agricultural commodities available for internal consumption will be generated by domestic food production. In most countries, data restrictions will require the use of a simple yield multiplied by area estimating procedure to arrive at estimates of yearly commodity production. Whenever more sophisticated methods have been developed at the national level, these should be used to replace the more simplified yield and area formulations.

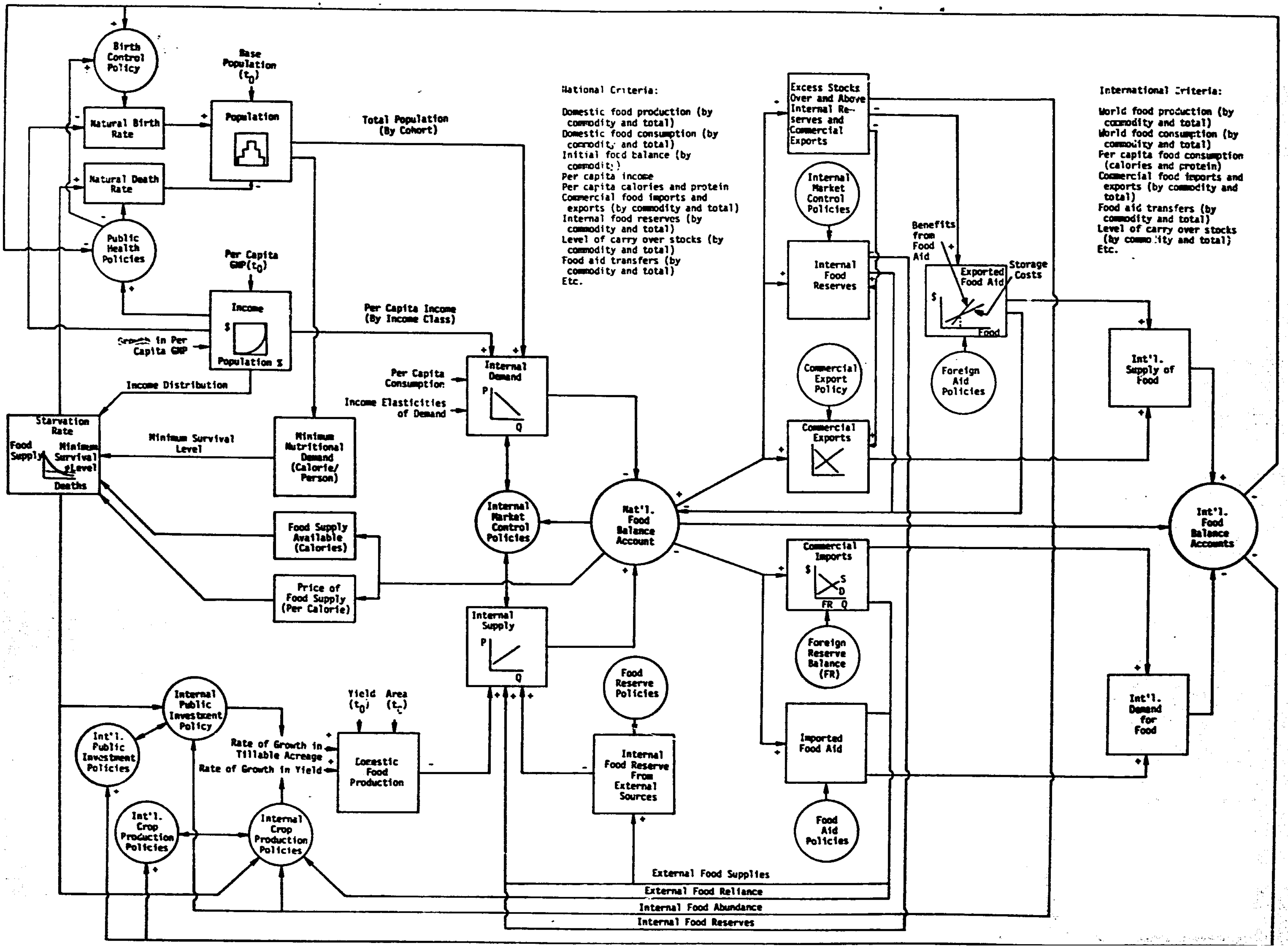

Figure 1. A Model Conceptualization.

Over time domestic output of agricultural commodities increases as the agricultural land base increases or as yields improve. Change in tillable area depends on three components: the rate at which multiple cropping practices are incorporated into the agricultural production system, the rate of flow of public and/or private capital investment committed by international and internal sources to land and water development projects, and the rate at which agricultural lands are being converted to nonfarm uses due to the increased demand generated by urban expansion.

The development of estimating procedures to predict changes in yields pose a much more complex problem than those associated with estimates of tillable area. Both the variety and intensity of factors ranging from specialized research, to improved farm management practices, to improved seed distribution systems all have some effect on yield. The level of involvement which a particular nation undertakes in providing these factors is dependent upon the divergence between actual food production levels and national food production goals. The greater the divergence, the greater the effort to provide programs directed toward improving internal yields. Funds for such programs may be generated either at the national or international level. Involvement of international organizations in the funding of such programs increases as the divergence between actual world food production levels and those necessary to maintain the existing world population increases.

The level of internal demand for food in any given country is directly related to the size of the population and the level of per capita income available for food purchases. In purely physical terms, as the population of a given country increases, the amount of food required to maintain it also expands. The rate of population growth is influenced by two basic factors: the natural birth rate and the natural death rate. In this initial formulation, net migration rates are not included under the assumption that they do not play a crucial role in determining a country's population level. Such an assumption may need to be revised in subsequent design rounds on a nation-by-nation basis.

With respect to birth rates, empirical evidence collected in both developed and developing nations tends to indicate a high correlation between increasing per capita income levels and decreases in the natural birth rate. The rate of decline in birth rates, although highly dependent upon income, is also assumed to be dependent upon the intensity of birth control services. The level and intensity of birth control policies at the national level is influenced by the degree of consistency these policies have with internal social and political conditions and the level of international support made available for such policies. The greater the divergence between food production and consumption, the greater will be the support for birth control policies. Internal financial support for such programs may be acquired by shifting funds away from public health programs to national birth control programs. The intensity of such programs will have a twofold effect on the birth rate in any given country. First, it will lower the point on the per capita income scale where a decline in the birth rate begins; and second, the higher the level of such programs, the greater will be the rate of decline.

As improved medical technology has become available to a greater number of people, the overall death rate throughout the world has dropped. It is assumed that as per capita income increases, the supply and intensity of public health services will also increase. Increases in these services may be affected by internal and/or external support of birth control programs. The decline in the overall death rate generated by increased public health services is expected to be partially counteracted if a decline in the general level of nutrition occurs. This concept is incorporated into the model through the calculation of an endogenously determined starvation rate. This rate is dependent upon a number of factors such as the minimum nutritional level required to maintain survival, the amount of food available for consumption measured in calories and protein, the price of food measured in dollars per calories and protein, the overall income distribution, and the urban rural-population distribution. Such a formulation assumes that as the price of food increases, persons in the lower income groups will experience a greater decline in their effective demand for food than those in the higher income groups. This decline will be unevenly distributed across lower income groups with respect to location. Some living in urban areas will migrate back to rural areas where food will be more plentiful, while others with rural ties will be able to augment their declining nutritional level with food "aid" packages solicited from rural donors. Others who cannot migrate and have no rural ties will be extremely vulnerable and will be forced to accept nutritional levels below those required for subsistence. Thus, the death rate amongst the urban poor and especially the children of the urban poor will be more sensitive to changes in price than that of upper and lower rural income groups and upper urban income groups.

National policies governing birth control, public health, internal crop production, and internal public investment are closely linked to a nation's food balance situation. In surplus producing countries the food allocative decisions are made on the basis of maintaining acceptable domestic prices, the use of a fixed budget for food aid, and the extent of pressure for commercial exports. In deficit producing countries these decisions depend on acceptable domestic prices, pressures on foreign exchange, which may be used for food importation and on ability to attract food aid.

The model defines and monitors the dynamics of the food-population situation in both deficit and surplus nations through the employment of a food balance account. This accounting mechanism which formulates the structure of the system provides two basic types of statistics, one which measures the absolute level of food being consumed in a country during any given time period, and one which measures the level of food self-sufficiency as indicated by a positive or negative balance. When a nation compares internal production with internal consumption and arrives at a negative balance, a number of policy options are available. It may choose to adopt policies which foster internal homogeneity (equity) by supplementing internal stocks with commercial imports, imported food aid or a combination of both. Such policies transfer real income through their downward pressure on price. Commercial imports are constrained by the level of foreign reserves held by the country and the policies governing those foreign reserves. Nations which estimate that they are unable to erase negative food balances via participation in the world market because of foreign reserve balance contraints may turn to imported food aid as a supplemental source of food supplies. The amount of such aid will depend on the food aid policies presently held by the nation and past alliances which have been forged with food surplus nations.

A second set of policy options which foster the concept of national heterogeneity (stability) falls under the general term of *triage*.[6] Nations may explicitly or implicitly maintain a negative food balance by not augmenting internal production with imports and allowing commodity distribution to proceed via domestic market price or institutional regulations. Under such policies the incidence of death due to starvation and related illnesses increases, foreign reserve balances are maintained for use in purchasing alternative imports, and the level of social and political unrest generally rises. Policies of this nature are not solely limited to deficit nations but may be followed by food surplus nations through policies which limit food aid or by international organizations through policies which limit research and investment funds. In the long run nations that have experienced initial negative food balances, (internal production less than consumption) will be moved by the need for political stability and food self-sufficiency to institute or increase the level of internal programs to remedy the food balance situation. Such programs may take the form of increased governmental expenditures in areas such as birth control, improved agricultural factor supplies, and public investment in agricultural infrastructure. The linkages between these policies and their effect on heterogeneity, homogeneity, equity, and stability within nations is a critical issue which must be articulated in depth in future modeling rounds.

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[6]The concept of *triage* was first used to describe the sorting process used in treating wounded soldiers. First priority went to those who were able to return to battle, second to those who were to be excavated and last priority to those fatally wounded. In the context of the world food situation, it refers to the sorting of national population groups or nations via policy design or rules of status quo. An excellent example of the implications of the concept in this context is found in Garrett Hardin, "Lifeboat Ethics, the Case Against Helping the Poor," Psychology Today, 9 (September 1974), 38.

If a nation experiences a positive food balance situation (internal production greater than consumption), excess supply may simultaneously flow to three destinations. Part may be used to augment internal food reserves which are used by the nation to control its own internal price structure and to guard against future contingencies. The remainder of the surplus will be sold, if possible, on the international market. Such surpluses flow to nations who are willing and able to pay the going market price. Sale of such commodities continues until the price received for the commodities is equal to the cost of production plus the cost of storing the excess supplies. Both production and storage costs are assumed to be highly contingent upon the mix of export policies adopted by the surplus nation. If a positive food balance remains after the demands of internal food stores and commercial exports are satisfied, the remaining stocks will be held in carry-over stores. Such stores are the major source of food aid provided by the surplus nation. The greater the level of such stores, the greater the holding costs and the more agreeable a surplus nation is in providing food aid. In addition, the greater the level of these internal stores, the greater the nation's involvement in internal crop production policies and internal public investment decisions aimed at limiting excess supply. The movement of food from these stores in the form of food aid and the designation of the recipients of such aid will depend on the foreign aid policies of the donor nation. Such policies are contingent upon the level of food aid earmarked for particular countries in the past and the degree of the negative food balance exhibited by a given deficit nation.

International food balance accounts similar to those developed at the national level will be generated by comparing the international supply with the international demand for food. Such a system of equations which defines the world food system should be formulated to examine the concepts of homogeneity, heterogeneity, equity, and stability at the international level. Within this structural component the international supply of food is assumed to be dependent upon the level of food aid and commercial export which occurs during any given time period. The international demand for food, in turn, is dependent upon the level of commercial imports and imported food aid required by deficit nations during any given time period. The international food balance account compares the international production with international consumption to arrive at an index of the international food situation. If world food consumption exceeds world food production, it is assumed that international organizations such as FAO, the Ford Foundation, etc., will be encouraged to provide either uniform or selective support for programs which will affect the birth control and public health policies of selected food deficit nations and programs which will funnel technical and financial assistance into international public investment and crop production programs. In addition, by simply summing international and internal production and consumption for various commodities across all nations, the international food balance account will be able to provide a picture of the absolute level of world food supplies.

In the model the food balance accounting mechanism must begin and end each time period at zero. Nations which experience positive balances will move toward a zero balance by depleting excess supplies through commercial exports, allocations of food to internal reserves, and through the creation of carry-over stocks which may or may not be used for food aid. Nations which experience negative balances may choose to augment internal deficits via commercial purchases, food aid or to follow a policy of *triage*. The existence of negative balances will result in deaths due to starvation.

These deaths generate a decrease in food consumption which will return the balance to zero.

It has become evident that national and international policies are extremely important in the conceptualization of the world food system. The above description has referred to a number of policy sets which might be used to affect change in various system components. These sets of policies have included such items as public birth control and health policies, international and internal public investment policies, international research investments and internal crop production policies, internal market control policies, commercial export policies, foreign aid policies and food reserve policies both in the food deficit and food surplus nations.

Toward a Modeling Capacity

The model outlined above has been conceptualized at a rather aggregated level relative to the detail required to make it operational. The modeling job implied is much larger and more complex than might appear in Figure 1. To develop an operationally useful model, both a modeling and an analytical capacity are required. The steps required to build a capacity for modeling and analyzing to solve problems are neither obvious nor easy. Several necessary components, however, can be identified. First, is a core team composed of trained disciplinarians with an affinity, an ability, and a willingness to work as members of a group. The basic structure of the team should include systems scientists, economists, and agriculturalists. Additional support, as needed, would be provided by demographers, sociologists, political scientists, public administrators, and a broader range of agricultural technical scientists. Its structure and location should facilitate linkages to decision-makers and to support units necessary for its functioning. Internal organization should be conceived and designed to facilitate both model development and problem analysis.

Major support units including a computer and library system should be developed. The computer system includes both hardware and a growing library of software routines and components usable by, and in many instances developed by, the multidisciplinary team. A centrally located data bank and information system pertinent to world food and agriculture should be developed in such a way as to insure easy retrieval and updating. In the initial modeling phase, major data sources would include organizations such as FAO, USDA, and the Population Council. In more sophisticated modeling rounds, a greater and greater amount of individual country data would be necessary. At this point, an ability to tap into country-level data acquisition systems and to work with country-level analysts would be crucial.

It is obvious that the ultimate scope of the work outlined in this paper is far greater than might be presumed at first glance. A truly Herculean effort is required to accomplish the task in the detail required by the problems at hand. A building block approach is imperative. And phasing is required. The first phase is to conceptualize and build a global food and agriculture system model based on national components and the appropriate linkages at the international level. This will lead to a second phase in which linkage with individual national research and decision-making bodies is accomplished for more detailed conceptualization and more sophisticated modeling on a nation-by-nation basis. Intense model development will likely be required over at least a 10-year period, with institutionalization into the decision structure at national and international levels becoming an important activity in the later half of the period. The model components should be viewed as capital stock to be used, adapted, and updated for continued analysis for many years into the future. As one set of problems is solved, others will emerge requiring analysis and solution. Only a major international cooperative endeavor will be able to institutionalize the modeling capacity and develop the appropriate models to meet present and future challenges. The clock is running. It is time to begin.

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