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MOIRA: FOOD AND AGRICULTURE MODEL

PROCEEDINGS OF THE THIRD IIASA SYMPOSIUM ON GLOBAL MODELLING, SEPTEMBER 22-25, 1975

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PREFACE

In the field of global modelling, IIASA has assumed a monitoring role. Whenever a major global model reached a state of completion, IIASA convened an international conference of scholars working in this field to discuss the assumptions, methodology and findings of the model prior to its final publication.

The first two IIASA global modelling conferences dealt with "Mankind at the Turning Point" (April/May 1974) and the "Bariloche Model" (October 1974), respectively. The subject of the their global modelling conference is "MOIRA" that is concerned with problems in the field of food and agriculture. The model was developed by a group of scholars from the Netherlands.

This topic is of particular interest to developing nations, and IIASA is greatly indebted to the United Nations Environment Programme for its support of this conference. As a result, IIASA was able to field the conference on a much broader scale and to include as participants a large number of experts from developing nations.. Their contributions proved to be of great importance, allowing an examination and discussion of the methodological framework of the models directly from a viewpoint of the needs of these nations.

These proceedings include invited papers and discussions; abstracts and reference to full publications are given for those papers that have been published elsewhere. Additional papers submitted to the Conference are available from IIASA as pre-prints; a list of these is given in Appendix 3.

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Table of Contents

Address to the Conference

J. Gvishiani

Ladies and Gentlemen, I was very much impressed listening to the discussions here today. I am sorry that, unlike other members of the Council, I had no opportunity to be with you earlier. Needless to say, the Council and the Institute are very grateful to you for your contribution to an increased understanding of the possible role of IIASA. The studies that most of you are involved in have great significance for the future of our planet; I am sure that you do not need to be persuaded of the importance of this area of research.

This Institute, as you know, is exceptional and unique, and is still in the development stage. We are trying to define the scope of our activities, and our influence on research that might be going on elsewhere; and we have concluded that our involvement in global studies such as those being discussed here should be strengthened. This was inevitable for an institution whose role is not to consider very abstract areas, but actually to implement something; that is why IIASA is the International Institute for *Applied* Systems Analysis. Our research in methodology--which as you know is a most important project of the Institute--will help us to define more clearly what we mean by "applied" systems analysis. And I think that the significance of the discussions here transcends the substance of the problem we are here to discuss: we are not only investigating food and agriculture and methodologies of global modelling, we are also seeking to enhance our understanding of what is lacking in international cooperation so that we can promote substantial progress in this sphere.

Many attempts of this kind are being made: this is our third meeting, there are other meetings, there is the work of the Club of Rome and other groups. More and more scholars are entering this field, but all complain that there is a lack of data and a lack of specific methodologies. It might be the role of the Institute to help, formally and informally, to bring together the scattered forces devoting themselves to these complex problems. We have another advantage though perhaps it is not yet being adequately exploited: we can bring together different cultures, different values, different perceptions, and so try to make a scientifically independent assessment.

May I just say a few words without entering into methodological areas too deeply. My own feeling--and I think some of you have commented in this direction--is that we will surely have a system of models, or if you wish a hierarchy of models, rather than a single model so comprehensive and extensive as to be all-inclusive. Today, with all the advantages and disadvantages of various models, we can try to identify the interaction between different classes of problems, of different magnitudes or levels of abstraction. Owing to the lack of knowledge or the lack of systematization of existing knowledge, scholars are faced with the choice of proceeding, knowing that the scientific background in a given area is inadequate, or of not going ahead at all. From this point of view, I feel that the Institute might be of great help, perhaps in cooperation with UNEP--such suggestions have been made several times--or perhaps with other institutions, both international governmental and national non-governmental, to collect objective data covering the whole spectrum of problems. This is something that the world scientific community must strive for, since we must necessarily reassess existing methodologies systematically. Along such objective lines one might then build up an understanding of evolution and future development.

I want particularly to emphasize--and this was always my reaction when faced with other models--that the omission of social and political trends practically makes a model senseless: these considerations, whether really normative to any degree, must be included. On the other hand, we realize how difficult it is to apply scientific methodology to forecasting in socio-political areas, though we may have to face the necessity of doing so. Thus I come back to my conviction that there must be a hierarchy of models, the most general of which--a really global model--inevitably has to be rather abstract. It should not include too many single facts known today, or which we might discover tomorrow we must bring facts into a more or less compatible form, bring them into the same class. Only then can we hope to understand real interactions and explain the behavior of the model as a whole.

Moreover, I feel that this model must be descriptive. If it is sufficiently descriptive, it is global, that is, at the highest level: a model of what is known today and how we can systematize the knowledge. The model itself is not the target; rather, it is an attempt to increase our understanding to the greatest degree possible, so that we can see the situation of the world as a whole. And then we must have a number of more normative models where directly or indirectly we are calling for certain actions. Here it will depend on existing knowledge, and our ability to systematize it and go ahead. This at least is the direction taken at the Soviet Academy of Sciences, where we tried on both the regional and the national level to develop forecasts that integrate the socio-political aspects into the socio-economic picture and take all natural resources into account.

If we are dealing with a very big, large-scale model--one model with which we seek to explain everything--we will inevitably be trying to deal with too many facts. And so we thought it might be promising to reassess our knowledge by using sectoral models, without attempting to interpret or forecast. I like the expression I have heard here: "conditional forecasting"--the conditional being derived from independent assessment of trends rather than from what we interpret into the model. Global modelling really forces a new outlook, a new approach. We are still in some measure slaves of the outlook we were born and raised with, but perhaps never before has a problem so urgently called for a new methodology. The real scholar--and this is how we want it at IIASA--will not come with certain prejudices and certain a priori knowledge; he will be objective, and open to the outcome of research. We want a team of scientists who do not limit themselves to in-house research but cooperate with interested national and international institutions in an effort to cope more systematically with the problems we all face.

Thus for an assessment of existing knowledge, we need a descriptive model, a global model; and then a number of subsystems, more specific models, become the subject of further investigation. So today we have chosen a specific topic for the third conference. Even at this level we see how extensively it is interrelated with other problems. This is much like what is happening within IIASA itself, what we are striving for: a redefinition of the research program of the three years of our existence.

I sincerely appreciate your attendance here, and we will be happy to have your advice--not only in tackling the questions that are the topic of our conference, but also on the role this unique institution should play. On behalf of the Council, may I again express my gratitude and wish you all success in your research. I hope that, meeting you here, we may establish closer, more formal contacts that may help us to deal with the important problems we all face.

Thank you, Mr. Chairman.

Welcome and Introduction to IIASA

Roger Levien

Thank you very much, Professor Bruckmann. I join you in welcoming everybody and in expressing IIASA's pleasure at hosting this third symposium on global modeling. I suppose most of you are familiar with our previous activities, but for those who are here for the first time, let me simply report that our first global modeling conference was held in the spring of 1974 and was concerned with the Pestel-Mesarovic model; our second conference held in the fall of 1974 was concerned with the Fundación Bariloche model. Each of the models was doubly global: "global" in geographic extent and in the number of sectors considered--each includes population, energy, resources and environment. Today, we are turning our attention to singly global models--that is, models that are global in geographic extent but that focus attention on one sector, that of food and agriculture.

This is an especially appropriate topic for IIASA to consider at this stage in our development. In a few weeks we will celebrate our third birthday. In October 1972, representatives of twelve Academies of Sciences and similar scientific organizations met at the Royal Society in London and signed IIASA's Charter. In the period since then two additional national organizations have joined the Institute. IIASA is now a non-governmental scientific research institution founded and supported by member organizations in fourteen countries. These are the Academies of Science of the United States and the Soviet Union, and Academies or similar institutions in the United Kingdom, Poland, the Federal Republic of Germany, the German Democratic Republic, France, Czechoslovakia, Italy, Hungary, Japan, Bulgaria, Canada, and our host nation, Austria. But our concerns extend beyond these fourteen countries. They are *universal* in the sense that we are concerned with issues that, although they lie within national boundaries are shared by all nations; and *global* in the sense that we study issues that cut across national boundaries and cannot be resolved by individual actions of a single nation. In the three years since the Charter was signed, IIASA has grown from a staff comprising a small group of scientists in May 1973, to a staff that now consists of about seventy scientists. Of course, there is a continuing flow and flux of scientists from different countries; but on the average we have seventy scientists coming from all our fourteen member countries, as well as from a number of other countries. Our annual budget has grown to over 100 million Austrian schillings (about U.S. $6 million) and our research program has grown from one to eleven projects.

The initial three year "start-up" period at IIASA is drawing to a close, and we are in the process of review from which we hope to learn from the experience of these first thirty-six months, in order to plan more effectively for the future. Several facts have become clear to us from this review of past experiences. First, with the current size of the professional staff and the budgets we are likely to have in the future, the initial eleven projects represent too broad a diversification of our scientific program.

We must now seek to coalesce them, to bring them together into natural groupings so that we can concentrate on truly important issues. Second, the topics that we define in any grouping have to be brought together in such a way that, even though we may reduce the number of projects from eleven to perhaps four or five, we can facilitate interaction and integration among this smaller number. And third, we have to focus attention on examining alternative strategies for meeting the growing and changing future demands, under the constraints imposed by our desire to have a pure environment, a stable social system, and satisfactory economic conditions. Furthermore, we must help to develop the methodologies by which others can share this quest both on a global scale and within their own homelands.

At present, we see the beginnings of some clustering. Let me use the description of these clusters as a way of telling you about our current research program and the direction of transition. At present, we are in the process of research planning, so what I say today may change tomorrow. I hope you will understand that I am describing a point on a trajectory.

One important cluster is that of studies concerned with population, human resources, and human settlements--that is, the way human beings are grouped on the earth's surface. Two projects in this area are currently underway at IIASA: one on urban and regional systems, and the other on biomedical, or health care systems. We are drawing them together as part of a broader concern for human resources and patterns of distribution on the globe.

A second cluster of concerns is the issues that arise both from the management of the large public and private organizations that affect our lives and are the instruments of our objectives and goals; and from the management of technology. Thus we are forming an area that focuses on management and technology, and will bring together economists, management scientists, and engineers. At present we have two projects that will become a part of this area, one on large organizations that has carried out retrospective studies of large regional development projects; and one on integrated industrial systems that has looked at integrated, multi-level management in the steel industry.

A third cluster is concerned with resources and environment. Obviously, this issue is at the center of interest of this conference. We have three projects that fit within this grouping. The Ecology and Environment Project has sought to develop, through a series of case studies, a science of ecological system management. Many of you may know of the work of C.S. Holling and his group on the management of forest pests in Canada, of salmon fishing in the Pacific, and of Alpine ecologies in Austria. A second project deals with water resources, and looks at the management of river basins. Third, the Food and Agriculture Project, under the leadership of Professor Ferenc Rabar of Hungary, will be of particular interest to this conference. This is a beginning project that we hope will grow and expand over the coming years to become a major cross-cutting theme at the Institute. Most of you will have the opportunity to speak with Professor Rabar during this coming week, and I hope that there will be opportunities for consultations since we are now at the critical state of initial planning for a large program in food and agriculture. His work represents the point of a wedge, which I hope will expand very rapidly during this coming year. Continuous and extensive efforts will be made to review current policy issues, to look at what has been done worldwide in addressing food and agricultural issues, and to define at IIASA a long-term program in food and agriculture.

The fourth grouping is concerned not so much with the applied policy aspects of our research, but with the methodological issues that cut across each of our probes into major policy areas. This group concentrates our interest on developing a science of systems and decisions. Currently we have two projects in this area. The Methodology Project was initially led by Professor George Danzig of linear programming fame; he was followed by Professor Tjalling Koopmans, the well-known mathematical economist, and later by Professor William Jewell. We have just welcomed Professor Michel Balinski, an applied mathematician from the United States, who will be staying with us for three years to develop a stable and broad-based methodological group at IIASA. The other project covers the computer sciences and has concentrated on computer networks and their role as tools of systems analysis both internationally and within our own institution. This project is led by Dr. Aleksandre Butrimenko from the Soviet Union.

I should say something about two other projects that do not fit into these four research areas. One is the category that we call General Activities. This is an important topic for us since it was under the leadership of the General Activities area at IIASA that our exploration, reconnaissance, and role as a catalyst and coordinator, or at lease disseminator of information about global modeling grew. The work on global modeling has gone on under the leadership of Professor Bruckmann and is now passing to Professor Rabar. The other project is one that I am close to personally. During my first year at IIASA I led the Survey Project which is concerned with developing a series of individual volumes on the international state-of-the-art of applied systems analysis. We have a number of initial volumes underway, about six all together. One of these will be on the methodology of global modeling, which will be co-authored by Professor Rabar, and Dr. William Nordhaus from Yale. We hope there will be contributions from many of you at this conference.

So, these are the groupings of IIASA's interests. As you can see, they are global in extent. The titles that I have mentioned span the sectors that one would be concerned with in any attempt at global modeling, or any integrated concern for future global development. Obviously, with seventy scientists we cannot hope to have depth in each of these areas. IIASA is not attempting to be self-contained, in the sense of having to do everything itself in each of these areas; rather it aspires to be the tip of an iceberg, the point where the work that is going on worldwide can be extended, used, and brought together. We can fulfill our role as a link among many teams represented here and elsewhere, and also we can add that additional increment of East-West exchange of scientific information.

Now, as I said earlier, these four or five basic areas should be linked. We have in mind accomplishing this at two geographical levels. First, we will bring together investigations of resources, human settlement, and management and technology at a regional level. We are developing at IIASA a cross-cutting program on integrated regional development that will look at the interaction between industrial, urban, environmental, resource, and other sectors in the exploitation of regions, especially those with rich natural resource bases. This work has begun with two retrospective studies: the first, which began with a conference last October in Baden, was a study of the Tennessee Valley Authority experience in developing the six-state region around the Tennessee River valley in the United States. That was followed by a field visit by an international team that looked carefully at the forty-year history of the Tennessee Valley Authority, its management techniques, and so on. This international team is headed by Professor Hans Knop from the German Democratic Republic. Some of the study team members are here today; you might want to speak with them about this work. They include Academician Abel Aganbegyan from Novosibirsk; Professor Gavriil Popov from Moscow State University; and Professor Andrzej Straszak from Warsaw. They are at present completing their status report, which will be given later this week; publication will follow. What is more important from our point of view, is that there will be a second retrospective study focused on the Bratsk-Ilimsk dam development in Eastern Siberia. This study is being organized and led by Academician Aganbegyan under Professor Knop's overall leadership. It will begin with an international conference here, and will be followed next summer by a study tour in Siberia. These two retrospective studies of large regional development efforts give us a base of experience from which to begin to consider the methodological and organizational issues of integrated regional development.

To give some cogency and practicality to this task, we intend to work closely with scientific organizations in our member countries and elsewhere on pilot studies. The first of these studies will be carried out in Poland, where a new regional development southeast of Lublin, is planned that will exploit major coal resource. Under Professor Straszak's leadership, we hope to have a joint association of the Polish group working on this regional development and the IIASA group. There is also a group in the southwest of the United States under the leadership of Professor Allen Kneese that, we hope, will also be associated with our study. We are seeking additional regions that can serve as pilots for our integrated regional development study. One way to bring together the many subtasks of our institute is to combine them in investigating the integrative development of a region.

The second gographical level at which the integration can occur, and the obvious one of concern to those attending this conference, is the global level. Here, too, we hope to cut across the separate tasks underway at IIASA, and to address issues of global concern. Our tactics differ slightly in this case. One possibility would be to study simultaneously, in an integrated way, the many sectors at the global level, as has been done in the Meadows' models, the Pestel-Mesarovic model, the Bariloche model, and so on. At present, however, we have chosen to pursue a strategy that focuses in sequence on major sectors; as our resources grow, we will add to them and also look at the integrative methodology. This is in part an intellectual choice, and in part a practical choice. The major project at IIASA, the largest one, the one which began first, and which has had the most public exposure, and I think in many ways has achieved the deepest scientific results, has been our Energy Project, under the leadership of Professor Wolf Haefele, from the Federal Republic of Germany. This project looks at energy in a number of dimensions, but has its major focus on medium- and long-term energy strategies at the global level. Thus at the Global level we are now trying to use this major energy study as an integrative focus for activities throughout the Institute. Soon, we will add to it our concern for food and agriculture, developed under Professor Rabar. And, as our resources permit, we will add environment and other major global concerns. At the moment, our tactics are to focus deeply on particular sectors so as to understand them well and then to build up from that level to more aggregative studies.

This conference is therefore timely in many ways for IIASA. We are currently planning a research program that has a global perspective, and a major food and agriculture focus. During the coming year we will build this study of global food and agriculture, do surveys of ongoing work, begin to do some modeling, data collection and problem identification. This Symposium is our way of giving a crystalized beginning to these efforts. We are looking forward to the discussions at the Symposium and to the recommendations and the information that the Symposium will provide. We welcome you and wish you success in the meeting today and for the rest of the week.

Introduction to the Conference

Ferenc Rabar

IIASA is a young institution with old traditions; one of these traditions is that of organizing conferences on global modeling. We are proud that several global modeling efforts have been presented first at IIASA.

Three years ago, Professor Dennis Meadows held an informal seminar within IIASA; his global model was already well-known worldwide. The first modeling conference organized by IIASA was held in the spring of 1974 at which Pestel and Mesarovic presented for the first time their global modeling efforts. The second conference held in the fall of 1974 was concerned with the Fundación Bariloche Model which was also presented for the first time. This third conference again introduces a new model, the outline of which was presented at Alpbach. But, I think that from the methodological point of view, this will be the first time that experts can discuss the technicalities of this model. Thus, this conference is a continuation of old traditions. But not only the traditions are important, but also the changes. At this conference we would like to introduce some slight changes. In general, conferences consist of a loose bunch of papers read as monologues by different people to an audience of "listeners". What we would like to have here is a dialogue, a comparative evaluation of the different models. So we expect participants to react to each other's remarks, to address each other and to relate their problems to the problems of others. If we think in these terms, you will understand how we tried to structure the agenda. The first day we will hear the presentation of this new world model, which is narrower than other models since it concentrates only on food and agriculture. This presentation will continue into the second day, after which we will hear reports of modeling efforts by the Bottomley group in the U.K. and by Kaya in Japan. On the third day we will discuss the submodels of food and agriculture that have already been presented in the different global modeling efforts. Comments will be heard from Donella Meadows, from representatives of the Pestel-Mesarovic group and of the Bariloche group. The afternoon session of the third day will be devoted to discussing not only the methodology but also the various aspects of food and agriculture problems; we will also assess some of the major problems in food and agriculture worldwide. Several of the papers to be presented deal specifically with this topic, especially those of Etienne and of Sanderson of the Brookings Institution, where a model will be developed in food and agriculture; at present the Institute has completed a clear assessment of the problem.

On the fourth day we will try to summarize all that has been accomplished in the previous days. We will hold a panel discussion at which the different models presented at the conference will be compared and evaluated by those who presented them.

In my opinion, there are two necessary things to bear in mind. First, those presenting their models should try to relate their concepts to those of the other models already presented. They should try to clarify their assumptions contrary to others, to mention the implications of their models as compared to others, and so forth. I would like, therefore, to ask those who will make the presentations to think in these terms.

A second point perhaps attacks the same problem from a different viewpoint. I would like to ask for the participation of those who are already well-known worldwide for their critique of global modeling. I mention here Professor Cole of the Sussex University, Professor Rademaker from Holland, and several other experts here who are equally outstanding and who know well all the global modeling efforts presented up to now. I ask them to listen to the different papers presented, bearing in mind these concepts, and to play the key role at the panel discussion.

That is our general idea about the structuring of the agenda and about the techniques we would like to use during the discussions. Now it is time to begin with the presentation of the papers.

Food for a Growing World Population

J. De Hoogh, M.A. Keyzer, H. Linnemann,
and H.D.J. Van Heemst

Introduction

1. The sudden scarcity of important basic foods and the unprecedented prices which have been asked on the world market during the last few years have drawn the public's attention to the uncertainty of the world food supply. In 1972 and 1973 disappointing harvests caused major shortfalls in international trade, and the world's stocks (particularly of grains) proved to be quite inadequate to absorb these shortages. The tripling of international grain prices which occurred in the period 1972-1974 meant an enormous decrease in purchasing power, particularly for the food importing countries, and also caused food aid programmes to be strongly reduced.

All this formed the reason for the World Food Conference held by the UN in Rome in November 1974, where plans were devised by which the world might be better ensured against the risk of fluctuations in food production (UN World Food Conference, 1974).[1)]

However, hunger and malnutrition are not only caused by scarcity and high world market prices, as has happened during the last few years. Even in times of low international prices and increasing surpluses, as in the 1960s, large groups of the world population are unable to obtain sufficient food. The situation on the world market is a very crude indicator of the relation between need and availability. Conditions on national and regional markets may be quite different to that on the world market. Moreover, the markets show only the demand of the well-to-do. Those with insufficient purchasing power (incomes) may still suffer hunger and malnutrition even though the market supply is fairly large and prices are low.

2. Just as other commodities, food is not distributed on the basis of need but on that of purchasing power. Many people in the world are so poor that they are unable to satisfy even their most elementary needs for food. The great majority of these people live in the developing countries where average incomes are low, partly because the level of agricultural productivity is very low - and the greater part of the population is engaged in agriculture. Moreover, income distribution in such countries is very unequal, and the incomes of a relatively large part of the population are below the average. The amount of available food is strongly dependent on domestic agricultural output. This applies to the many small farmers who produce chiefly for their own use. But it applies also to the developing countries whose means are insufficient to allow them to import in such quantities that domestic food supply can be made independent of domestic production. Roughly two-thirds of the world's population live in countries that are so poor that they depend for food chiefly on the fairly low production that takes place within their own borders.

Research into World Food Supply

3. The occurrence of hunger and malnutrition is a structural problem which unfortunately is likely to gain in severity. The strained relationship between food needs and food production is likely to be increased by the rapid population growth in the developing countries. According to the first report drawn up on the initiative of the Club of Rome (Meadows, 1972),[2] the world food supply - assuming a continuous growth of population and industrial production - in the course of the 21st century will stall catastrophically against the natural limitations of agricultural production. The second study (Mesarović and Pestel, 1974)[3] is also very somber in its opinion of future world hunger and malnutrition.

Since 1972, the Economic and Social Institute of the Free University of Amsterdam has been engaged in investigating by which factors the evolution of production and the use of food in various parts of the world are determined. This study is concerned particularly with the year 2010, when the world's population will be roughly twice as large as in 1970.

The research was initiated on the suggestion of the Club of Rome, and is carried out in close cooperation with the Centre for Agrobiological Research (CABO) at Wageningen, the Department of Tropical Soil Science of the Agricultural University of Wageningen, and the Institute of Agricultural Economics at The Hag.e The study is based primarily on FAO data.

4. Within the framework of the research much data have been compiled regarding global production and consumption in the base year 1965. A few figures are given below and also in Tables 1 and 2:

- in the industrialised nations (the Western market economies and Eastern Europe including the USSR), which house 30 percent of the world's population, more than half of the world's food is produced and also consumed. Seventy percent of the world's population therefore has to make do with less than half the total amount of food;
- food production per head of total population of a country is usually higher in countries with higher levels of income and wealth. In North America, for example, six times as much food is produced per head of population as in South Asia. Moreover, North America uses a much smaller percentage of its working population to produce this food than is the case in South Asia;
- per capita food consumption in a country is closely related to the national per capita income. In the richest countries the use of vegetal raw materials is four times as great as in the poorest countries; expressed in calories, however, the ratio is 1.5 : 1 because in the menu of the rich consumers the share of animal products, for example, is relatively large;
- calculated per head of the world population, there is sufficient food; if it were evenly distributed no-one would need to suffer deprivation.

5. There are many technological methods by which food production in the world can be increased. On the basis of a detailed inventory of soil characteristics, rainfall, temperature and sunshine, the Wageningen members of the team have calculated that - according to natural restrictions to the growth of agricultural crops - the earth is capable of pro-

Table 1: Actual and potentially suitable agricultural land; actual and maximum agricultural production

	(1)	(2)	(3)	(4)	(5)	(6)
	arable land in '1965'	potentially suitable agr.land	(1) in % of (2)	agric. prod. in '1965'	maximum agric.prod.	(4) in % of (5)
	mln. ha	mln. ha		10^8kg cons.prot.	10^8kg cons.prot.	
REGIONS						
North America	220	546	40	397	7159	5.6
Western Europe	129	147	88	233	2192	10.7
Japan	6	8	72	29	111	25.9
Australia etc.	59	284	21	86	3723	2.3
Eastern Europe (incl. USSR)	288	522	55	322	6042	5.3
SUBTOTAL Industrial economies	702	1507	47	1067	19228	5.5
Latin America	122	695	18	173	14599	1.2
Middle East	52	111	47	35	1038	3.4
Tropical Africa	174	643	27	91	11681	0.8
Southern Asia	266	382	70	248	7520	3.3
China c.s.	111	349	32	267	3992	6.7
SUBTOTAL Developing countries	725	2180	33	815	38830	2.1
World	1427	3687	39	1882	58058	3.2

Note: '1965' refers to the average over the years 1964-1966.

Source: Calculations mainly based on FAO data.

Table 2: Food production and food consumption in '1965'

	Food production[1] per caput	Food consumption[2] per caput			Ratio of consumed protein to consumable protein
	kg consumable proteins/year	in kg consumable proteins/year	in Kcal./day	in gr.of consumed proteins/day	
REGIONS					
North America	152	104	3180	97	0.34
Western Europe	49	81	3015	90	0.41
Japan	19	55	2501	87	0.58
Australia etc.	92	55	2942	88	0.59
Eastern Europe (inc.USSR)	74	74	3169	94	0.46
SUBTOTAL industrialized economies	76	80	3047	92	0.42
Latin America	47	43	2485	66	0.57
Middle East	27	32	2234	64	0.72
Tropical Africa	29	26	2160	60	0.85
Southern Asia	24	26	2002	52	0.73
China c.s.	30	30	2060	61	0.75
SUBTOTAL developing economies	29	29	2100	58	0.72
World	44	45	2398	69	0.55
INCOME CLASSES[3]					
< 100 $/cap.	24	24	1995	53	0.80
100 - 200	26	27	2062	55	0.73
200 - 400	32	32	2148	61	0.69
400 - 800	52	49	2718	79	0.59
800 - 1600	57	70	2988	91	0.47
> 1600	106	98	3150	95	0.35

1) of agricultural origin

2) fish included

3) countries classified according to average per caput income in '1965', in dollars of 1965.

Note: '1965 refers to the average over the years 1964 - 1966

Source: Calculations mainly based on FAO data ducing 30 times the present amount of food (Buringh, Van Heemst and Staring, 1975).[4] A great deal of agriculturally-suitable land is not yet used; but above all, production per hectare could be considerably increased. According to these data, there ought to be sufficient food both now and in the future; the world food supply is thus not primarily threatened by the finiteness of the earth.

This fact represents a point of departure for further study rather than a conclusion in itself. Maximum production is calculated on the hypothesis that all growth circumstances which can be influenced by man are optimal. That is to say: perfect water management, soil cultivation, fertilisation, maintenance, pest control, and environment protection. A hundred percent satisfaction of these conditions would require a tremendous input of capital, labour and knowhow, not only in agriculture itself but also in the associated infrastructure. And this is the core of the problem: which factors determine or restrict the rate at which the input of production factors in the agrarian sector increases, allowing greater use to be made of the very great production potential? This was the central problem to be examined by the research team.

The calculated non-utilised 'capacity' for food production is thus merely an indication that the world food supply is not endangered by the limitations of 'mother nature' - for the coming decades at least. But nothing has been said so far about the probable developments in that period, because these depend above all on a complexity of economic, social and political factors.

A Model of the World Food Situation

6. An in-depth analysis of the world food situation is necessary if we are to learn on which factors the future developments of food production and consumption in various parts of the world will depend. The focus of the research therefore lay in an attempt to explain the circumstances and relations which characterise the world food supply and its development over time. The complexity of the linkages in national and international relations and the necessity for quantification were the reasons why this explanation has taken the form of a mathematical model, given the name of MOIRA: Model of International Relations in Agriculture.

A model shows reality in schematic form. The manner and degree of formalisation depend to some measure on the purpose of the research. This particular research was intended primarily to increase insight into world-wide linkages and their significance for the development of the food situation in various parts of the world. It is an attempt to expand on earlier world-wide model-type studies, at least for as far as the food sector is concerned. With this objective in mind, an attempt has been made to describe human behaviour in the food supply process, not only of consumers and producers but also of governments which may exercise a significant influence on the domestic food price level, for instance, and in this way on the purchasing power of consumers and on the incomes of the agricultural sector. The introduction of government behaviour is also an essential element in the analysis of international linkages that exist through the world food market.

7. The volume of production and consumption of food is measured in kilograms 'consumable protein', i.e. the amount of proteins present in all vegetal agricultural products which are edible for the human being, plus the proteins in animal products for as far as these are generated by vegetal cattlefood which is not suitable for human consumption (roughage waste etc.). Total agricultural product is expressed in this unit, and substraction of the amount of protein in non-food products (wood, cotton, wool etc.) yields food production. It is assumed that the share of non-food products in total agricultural product remains equal over time, or is anyhow given exogenously.

Total consumption, expressed in this unit, shows the demand made by the use of foodstuffs on primary soil production in agriculture. Processing losses (e.g. by the production of meat on a grain basis) entail that 'consumable' does not equal 'consumed'. The relation between consumable protein and consumed protein varies strongly with the income level of the consumers; between countries, the averages vary between 1.2 and 3 (see Table 2, last column).

8. MOIRA describes from year to year the production and consumption of food per country or group of countries. There are a total of 106

geographic units; results are shown for the sake of convenience for ten regions of the world only.

The agricultural sector of a country is the smallest unit as far as production is concerned; in the model, therefore, 106 production units annually take a certain decision regarding the level of production.

Consumption is given more detailed treatment. Average food consumption per capita of a country may mask great differences within that country's borders, particularly as regards income inequality, and throws insufficient if any light on possible hunger. With this in mind, the consumers of each country (with the exception of the three centrally planned country groups) have been divided into income classes, six for the agricultural population and six for the non-agricultural population. For each year the model thus calculates the food consumption of roughly 1250 consumer groups.

9. The model explains the size of agricultural output as depending on the efforts of the farmers (the agricultural sector) to combine so many variable production factors with the (short-term) given inputs (in particular, labour and soil) that their incomes (i.e. the value-added of the sector) are as high as possible. The prices of end-products and of means of production are taken as a given that cannot be influenced by the agricultural sector; it is also assumed that the farmer bases the expected price for his end-product on the prices he has received in preceding years.

Furthermore, the producer is assumed to be familiar with the technicalities of the production process under the prevailing natural circumstances. These technical relations are described by the model with a production function, estimated with the aid of a cross-section over 106 countries. In this comparison, yields per hectare are assumed to be dependent on the amount of labour and of labour-substituting capital available per ha (the so-called operating capacity), in such a way that enlargement of this input per ha is subject to diminishing returns. The curve approaches asymptotically the maximum possible level of yield per ha mentioned above, determined ex ante for each of the 106 countries. This so-called soil-intensity function relates agricultural output and operating capacity not to actual agricultural area but to the total area of each country that can potentially be used for agricultural purposes. In effect, this means that the two forms by which production can be augmented - i.e. increased yields per ha and increased area of agricultural land - are not differentiated; they are described by one and the same technical relationship. This strategam was adopted due to lack of data. As a result, it is impossible to distinguish which of the two forms of production enlargement (or a combination) gives rise to the production growth generated by the model over the course of time.

The production function is coupled to a demand function for fertilizer; the latter is therefore considered as a production factor which is complementary to the input of labour and labour-substituting capital.

Movement along the production function derived from cross-section data is only possible if the level of production technology changes. It is assumed that in the long term technological improvement will actually occur if producers strive to attain higher yields per ha; technological developments in the model are thus endogenously determined. In the short term, however, the given level of technology can make it impossible to achieve higher production. Changes in the level of applied production techniques require time (research, training, infrastructural investments, etc.). This time factor is accounted for in the model by built-in limitations to the growth rate of total production and to the rate at which the amount of capital used per unit of labour may change.

The size of the agricultural product in any given year is dependent not only on decisions taken by the producers. Chance fluctuations in the harvest as a result of weather conditions, the occurrence of disease etc., are introduced into the model on a regional basis by assuming the repetition of annual harvest fluctuations over a historic period.

10. The amount of agricultural labour used in any year is taken as given.

In the course of time, this important production factor is subject to change as a result of two developments: natural population growth and the outflow of people from agriculture to the non-agricultural sector. The model explains these changes as being due in particular to the income inequality between the agricultural sector and the rest of the economy;

the distribution of population over the agricultural and non-agricultural sectors also plays a role.

11. The behaviour of the food consumer is described by a consumption function which explains per capita use of consumable proteins as determined by per capita income and food price levels. This function has also been estimated with the aid of a country cross-section in which allowance is made for the distribution of income within the respective countries. In addition to this relation regarding the consumed volume of elementary agricultural products (measured in consumable proteins), a second function shows the relation between the consumer's food expenditure and the size of his income. Combination of these two relations gives the value increase due to processing of primary raw materials (in the form of both processing within the agricultural sector and in the food industry). This value increase due to processing, which partly determines the difference between the producers' price level of agricultural raw materials and the consumers' food price level, is in turn strongly linked to a country's level of prosperity.

12. With regard to the behaviour of governments of the various countries, it is assumed that they try to establish a certain distribution of income between the agricultural sector and the rest of the economy with the aid of the domestic food price level. This sectoral income distribution thus reflects to some extent the political power relations which pertain between urban and rural areas, and which are in turn connected to the prevailing material and institutional circumstances. Using again cross-section analysis, an attempt has been made to link the great differences which exist between countries with regard to the relative income position of the agricultural population with such characteristics as agriculture's share in the national income, population density, and actual per capita income in agriculture. This statistical analysis can only partly explain the differences between countries; the remainder is attributed to institutional factors which are difficult to measure, and is therefore taken up as a structural characteristic of the government's behaviour in the country in question. The government is thus accredited

with an objective via this parity function which is endogenously generated by the model. From this follows the ratio which it tries to attain between agricultural and non-agricultural per capita incomes. From this income ratio the model derives the desirable domestic price level of food products (given the prices of production inputs purchased by agriculture and given the level of technology in the domestic agricultural production process). The price level defined in this way may be considered as the market price, corrected by any other income transfers (positive or negative) through taxation and subsidies, expressed per unit of output.

It is assumed that the government principally uses market intervention as the method with which to achieve its agricultural income policy target. Further, that the instruments of this price policy consist of trade policy measures which are intended to keep clear of disruptive price influences from the world market. Such measures (levies or subsidies on imports and exports; quantitative restrictions on foreign trade) have their consequences for the government budget. Under certain circumstances the desired domestic price policy may strand on prices that would be too high for the national treasury (for a food importing country at high world market prices; for a food exporting country at low world market prices). The desired domestic price level will then be impossible to maintain; if the budgetary burden is too high, world market prices will influence the domestic prices. The price policy in the model is therefore subjected to budget restrictions (expressed in a percentage of the income of the non-agricultural sector).

This also introduces the significant fact that wealthy countries (because they are rich) are better able to isolate their domestic food markets from the world market than are the poor countries whose much smaller budgetary capacity will usually be far sooner exhausted.

13. With regard to the centrally-planned economies, distinguished as Eastern Europe including USSR, China et al, and Cuba, it is accepted that decisions regarding agricultural production are taken by central government on the basis of material objectives, and not on the basis of price levels. It is assumed that these (groups of) nations wish to achieve self-

sufficiency in domestic food needs. The model derives increase in demand via the consumption function from the growth of national product and of population (exogenous variables). Labour is withdrawn from the agricultural sector to the extent that it is needed to realise production growth in non-agricultural sectors. If agricultural output does not equal domestic demand (e.g. because of harvest fluctuations), some amount of import or export may take place.

Lack of data made it impossible to distribute consumers in the centrally-planned economies into income classes. The model thus calculates average per capita food consumption solely on the level of country groups. Hunger and malnutrition for this part of the world's population are therefore not shown.

International Relations

14. The behaviour described above of the most important groups of actors in the food provision sector determines how the production and consumption of food in the respective countries (or groups of countries) will react over time to economic developments outside the agricultural sector and to population growth, two important exogenous variables in the model.

Developments in the food supply sector in various parts of the world are not independent of each other. Price formation on the world food market brings the national markets into contact with each other to a greater or lesser extent, dependent on the competitive conditions pertaining on the domestic market and the restrictions on national food market policies. Moreover, the international price level affects real national income for as far as the latter is dependent on import expenditure or on food export receipts. The domestic price level is the result of the price level aimed at by government and of the effect of the world market price. This latter variable results from the total of demand and supply positions of the countries in international trade. The model's itirative procedure calculates the world market price which, partly through its effect on national incomes and possibly also on domestic prices, brings total consumption and supply into equilibrium. Allowance is made for the fact that international trade can partly bridge imbalances between demand and supply by means of stockpiling.

The domestic price level that is related to this equilibrium price in international trade is an important variable in producers' decision-making regarding the size of the coming year's supply.

15. The balancing mechanism represented by the world market is very defective in its functioning. Food consumption is not particularly sensitive to price changes on the world market, especially in the rich countries. This is primarily a result of their high level of prosperity; the price elasticity of the total demand for food is consequently small, while the national incomes of these countries are also relatively insensitive to changes in the value of food imports and exports. Secondly, the rich nations protect their domestic food prices to a strong extent against international price fluctuations. The result is that consumers in these countries are very little affected by possible scarcity or surplus on the world market, and their consumption patterns remain almost unchanged. This considerably increases the instability of the world market. Major world market price increases can be caused by scarcities resulting from poor harvests, certainly if stocks are insufficient. Importing countries which are too poor to protect their domestic markets against such massive external influences are then forced by the high prices to adapt their consumption patterns. In this market constellation the financially weak countries thus fulfil a buffer function, although their consumption patterns offer them the least latitude. This characteristic of the model seems to be a fairly faithful representation of reality as shown by the experiences of the past few years.

Over the years supply of agricultural products in the richer countries shows the greatest sensitivity to price changes. As the agricultural sector becomes more market-oriented - both as regards the sale of products and the purchase of means of production - an increase in food prices, ceteris paribus, has a relatively greater effect on income and therefore is a stronger incentive to invest. It is true that producer prices in the rich countries are strongly protected by government against developments of prices on the world market, but the model shows that even the assumed restricted percolation of international price influences has undeniable effects on total supply. In this respect, too, the model seems to be fairly realistic; consider, for instance, the Common Market's expansion of the sugarbeet area in reaction to high international suger prices, or the strong expansion of wheat production in the USA after 1972.

High world market prices as a result of poor harvests and insufficient stocks thus have the greatest effect on the poor countries inasfar as consumption is concerned; but with regard to production, the reaction is to be expected sooner in the agricultural sectors of the rich nations.

Exogenous and Endogenous Variables

16. Although given incidental mention above, the exogenous variables of the model are to be mentioned explicitly:

(i) Economic development outside the agricultural sector. Although the growth of value-added outside agriculture is in reality not independent of agricultural development (certainly not in the developing countries), in our partial agricultural model we have been forced to assume a one-sided external influence. In simulations with the model up to the year 2010 the accepted income growth in the non-agricultural sector is derived from Leontief's latest long-term projections regarding the development of national incomes of many groups of countries, as modified by the World Bank.[5)] Since it may be accepted that in the process of economic development the non-agricultural sector will grow more quickly than the agricultural sector, the growth rates of the non-agricultural sector are assumed to be somewhat higher than Leontief's overall growth rates, in particular for countries where agriculture still has a significant share in the national income. To justify to some extent the mentioned relation between non-agricultural development and the increase of agricultural production, the exogenous growth rates have been lowered for the poorest countries if they were hard to reconcile with the endogenously calculated growth in agriculture.

(ii) Population Growth. Here, too, treatment as an exogenous variable leaves out of consideration any feedback of the food sector to this variable. It is quite conceivable that hunger and malnutrition (and the level of wellbeing in general) are of influence on demographic variables such as birth and death rates. However, uncertainty as regards the sign, size and time dimension of these effects forced the model builders to choose between a strongly hypothetical treatment of these linkages, and the simple introduction of population growth as exogenous variable. Preference was given to the latter. The population growth rate assumed in the model simulations is based on the latest UN prognoses, as elaborated by the World Bank.[6)] These growth rates have been used for both the agricultural and non-agricultural populations.

(iii) Income distribution. In order that hunger and malnutrition should become clearly perceptible, the agricultural and non-agricultural populations of market economy countries have been divided into six income classes with their respective shares in total sector incomes. This classification is made or estimated on the basis of data (sometimes very scanty) about income distribution in the base year 1965. It is assumed that this relative nominal income distribution per sector per country will remain unchanged during the period investigated (until 2010), notwithstanding the nominal increase of total incomes which will occur. Here, too, it is necessary to mention the arbitrariness of this assumption. However, theoretical and empirical information regarding the relation between economic development and income distribution (whether in or outside the agricultural sector) is so defective that any semblance of an integral approach has been avoided by introducing income distribution as independent of other exogenous magnitudes or of endogenous developments.

(iv) Price developments of agrarian production factors. The use of fertiliser and of mechanical aids is determinant in the model for the size of agriculture's annual purchases in the non-agricultural sector. The actual price development of these inputs is considered as an exogenous datum. A separate model has been developed for fertiliser in which, based on the cost structure of investment, transport and distribution, the course of future product prices is estimated. Price developments for raw materials (oil, gas, coal) and of investments prove to be the determining factors; physical scarcity of raw materials for fertilisers is apparently not likely in the period until 2010.

17. Over the period 1975-2010 the model generates a large number of endogenous variables. The results of the model simulations are presented in a selection of these variables for groups of countries. Obvious figures in this connection include the size (in kilos of consumable protein) of food production and food consumption, in total as well as the average per head of population. From this can be calculated the degree of self-sufficiency in food. Also, the size of agricultural and non-agricultural population is given for each year. Further important variables include the indicator of the world market food price and the size of world stocks.

The occurrence of hunger is a vivid criterion of the world food situation. The model calculates for the market economies the number of people who have less food at their disposal each year than the minimum norm. This food norm varies from country to country, dependent on the age structure of the population and the make-up of the food package. On average, the norm is 25 kilos of consumable protein per person per year. It will be clear that the calculated total of underfed people can be a global indicator of the extent of hunger, and that the development over time of this variable is more telling than the absolute number.

In view of the divergence of interests between agricultural and non-agricultural population as regards food prices, the model distinguishes between hunger inside and outside the agricultural sector. Gross and net hunger are also distinguished, the difference being the effect of (possible) food aid.

Uncertainties with regard to Long-term Developments

18. With the aid of MOIRA we first examined how the world food situation will develop in the period until 2010 under the assumptions mentioned above regarding the exogenous variables.

According to the model, the comparitively fast economic growth in the non-agricultural sector and the related increase in food demand will cause a relative scarcity on the world market (see Table 3, column 1, and the figures 1, 2 and 3). The international price level will fluctuate between prices which will be 2.5 - 4 times as high as the price level in the base

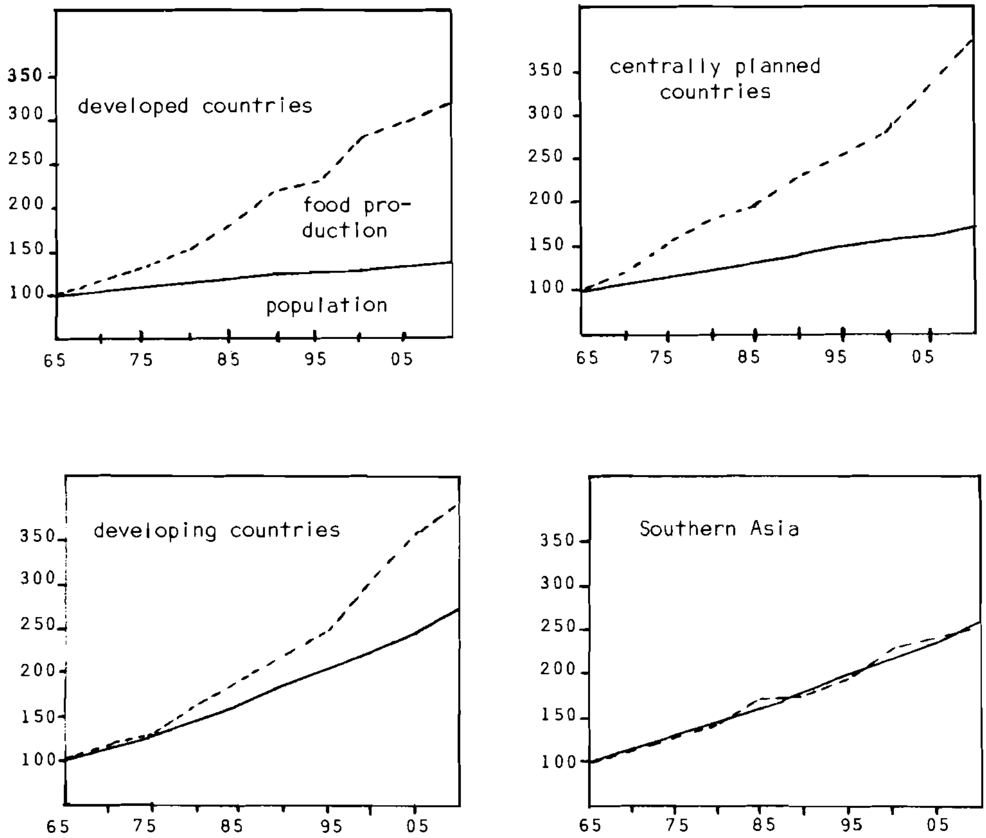

Figure 1

Development of population and volume of food production in regions of the world until 2010 (indices 1965 = 100) under the assumption of unchanged policy and relatively high income growth outside agriculture (comp. Table 3, column 1).

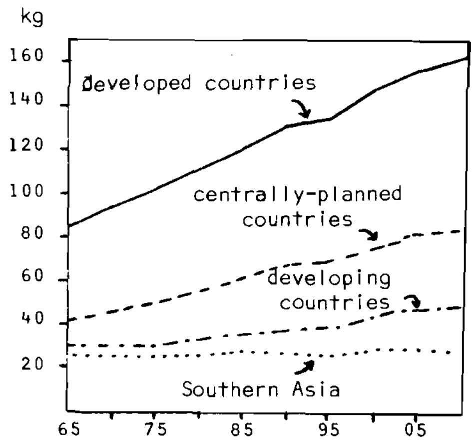

Figure 2

Food consumption per caput (in kg consumable protein) in regions of the world (assumptions as in Fig. 1).

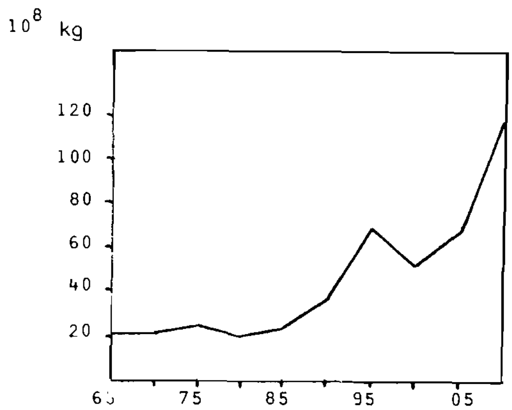

Figure 3

Development of hunger in the world: food deficit (in 10^8 kg consumable protein) of people with a consumption below minimum food standard (assumptions as in Fig. 1).

year 1965. In the year 2010, the world food production will be more than 2.5 times as high as in 1975 and will thus increase slightly faster than population growth. Nevertheless, during this period the number of people who have less than the minimum necessary amount of food will quadruple to a total of about 1.5 billion. Average consumption per head of population will hardly increase in the densely populated developing countries (in particular South and Southeast Asia); hunger will mostly expand in these countries, especially among the non-agricultural population whose numbers will increase strongly. In the rich countries, but also in Latin America, Tropical Africa and the Middle East, per capita food consumption will burgeon considerably. The differences in the world will thus grow even greater (fig. 2). According to these model results, North America will strengthen its position as important exporter of basic foods.

Developments in the world food supply situation prove to be rather sensitive to the growth rate of incomes outside the agricultural sector which increase the demand for food but also influence the rate at which labour will leave agriculture. In order to test MOIRA's sensitivity to this exogenous variable, an alternative simulation run made use of halved growth rates for non-agricultural income (see Table 3, column 8). The model then calculated world market prices which were far lower than those in the standard run, fluctuating now around the price level of the 1960s. Food production will double in the period 1975-2010, just keeping pace with population growth. Hunger in that period is on average almost 50 percent greater than in the standard run, as a result of lack of food in rural areas. In the densely populated Asian countries, average per capita consumption decreases.

19. The rate of population growth is also an important factor. An alternative simulation run with growth rates that are 50 percent less than the UN figures in the standard run shows that the extent of world hunger will then increase less (in 2010 twice that of 1975).

In order to test MOIRA's sensitivity to income distribution, the effect on the food situation of gradually decreasing internal income inequalities (to only 50 percent of their original magnitude) was considered. It appeared that, under this assumption, the number of people who will obtain less than the minimum necessary amount of food will 'merely' double during the coming 35 years.

20. Varying degrees of uncertainty exist with regard to the future developments of all these exogenous variables. In view of the sensitivity of the world food situation to these developments, MOIRA has only very relative value for prognostic purposes. Its utility is chiefly in illustrating the cumulative short and long-term effects of a certain external influence or of a purposeful political intervention on developments in world food production and consumption. This characteristic of the model is used to evaluate different forms of internationally-coordinated food policies whose aim is to eliminate hunger in the world, or at least to minimise it. This objective is relevant under all circumstances. All simulation runs with alternative assumptions regarding exogenous variables have one thing in common: if policies remain unchanged the number of people who cannot obtain sufficient food will increase. MOIRA conveys this impression with some certitude.

Policy Alternatives

21. The following policy measures were examined to see in how far they could eliminate or reduce the extent of hunger in the period 1975-2010.

(a) Measures intended to achieve redistribution of the available food in the world:

- reduction of food consumption by the rich countries (Table 3, column 2);
- food purchases by an international food aid organisation (financed by the rich countries) which will distribute this food to the underfed population groups (Table 3, columns 3 and 9);

(b) Measures intended to stimulate food production in the developing countries:

- regulation of the world food market in order to stabilise international prices; the price level pursued on the world market is a policy variable whose influence is tested (Table 3, columns 4, 5, 10 and 11);

- on the other hand, the effect which liberalisation of international trade would have on developments in the world food situation is also examined;
- a third scenario in this category assumes that the governments of developing countries wish to achieve higher incomes for the agricultural sector than ensues from the institutional income distribution between agriculture and non-agriculture which is in first instance maintained in the model (according to the so-called parity equation).

In the first instance, these policy measures were tested as to their individual influence on the development of world hunger. Based on these findings, combinations were designed in order to establish which packet of measures within the framework of international policy would be of the greatest benefit to world food supply during the coming 30 years (Table 3, columns 6, 7 and 12).

22. According to MOIRA, moderation of food consumption in the rich countries will in itself not lead to any improvement in the food supply in the countries where great hunger prevails (Table 3, column 2). On the contrary, in fact. The reduction of effective demand, which is what such a consumption restriction amounts to, will drastically lower world market prices and thus curb the growth of agricultural production; this will occur in both rich and poor countries. On balance, therefore, such a policy would have an adverse effect: hunger would increase more than if policies remaind unchanged.

Secondly, we examined whether food aid, financed by the rich countries, would be able to banish hunger from the world. It was assumed that food aid could be supplied with 100 percent efficiency, i.e. that the total food shortage of all hungry people could be cancelled-out by the provision of food that is not handled by the market. It is assumed that the necessary food will be purchased with the aid of funds contributed by the rich countries. MOIRA shows that it will thus be possible to reduce hunger to almost zero - if sufficient financial means become available. On the average, over the period 1975-2010, this redistribution of food would demand each year about 0.6 percent of the national incomes of the rich nations. Such food purchases would be accompanied by the phenomenon of a significantly higher world market price level for food; on the one hand this would stimulate production, but on the other hand it would have a negative effect on the purchasing power of non-agricultural population of the developing countries. 'Gross hunger' (i.e. before food aid is given) is therefore somewhat higher than in the standard run (Table 3, columns 3 and 9).

23. Food aid, however necessary it may be to alleviate acute need, is a measure that must in principle be temporary. The developing countries will have to achieve a structural improvement of their food supply primarily by increasing their agricultural production, because the relatively large agricultural sector uses a great deal of labour and land which has little if any alternative use. With this in view, measures which would stimulate this development were considered; in particular, the importance was examined of the world market food price level, which the rich countries are able to influence by means of their policies.

A deliberate world market price policy, aimed at maintaining a relatively high and stable price level, was proved by MOIRA to stimulate production growth in the poor countries. This favourable effect is largest for the simulation runs which assume moderate economic growth (Table 3, column 11). If policies remain unchanged (see under 18 above) the world market will have to contend with surpluses and low prices, and average per capita consumption in the densely populated countries of South Asia will decline during the period 1975-2010. The introduction of a policy of stable and relatively high prices on the world market (realised by the rich nations) would cause the food situation in developing countries to improve as a result of faster production growth.

The alternative runs which assume faster economic growth show similar reactions, although less pronounced, because by unchanged policy the world market price level is already relatively high (Table 3, column 5).

24. Regulation of the world market as intended under 23 above, assumes a fundamental change in the position which the rich countries take in the international trade in food. It is assumed, namely, that these countries will jointly fulfil a buffer function on the world market by financing stockpiles which will be sufficient to bridge the yearly fluctuations in supply and demand. In addition, it is assumed that the rich nations will absorb the structural imbalances in world food supply by a coordinated import and export policy that is oriented towards maintaining a particular world market price level. To fulfil this latter function, the wealthy countries will need to be able to influence their own production or consumption (dependent on the circumstances) in such a way that their net position on the world market will support the internationally-agreed price policy.

According to the model simulations, such regulation of the import or export balance is essential if the long-term target is to be achieved. Under the assumption of rapid economic growth, the maintenance of a relatively high price level on the world market will not demand much effort on the part of the rich countries. In any single year it might be necessary to restrict their own consumption somewhat in order to prevent the world market price rising above the intended price level (Table 3, columns 4 and 5). The higher this target price, the less the necessary consumption restriction.

However, if the world's economic growth were to slow down, the envisaged regulation of the world market would require fairly drastic measures by which to limit the growth of food production in the rich countries (Table 3, columns 10 and 11). In fact, these countries will have to significantly curb their supply to the world market if the desired price level is to be maintained. In the relevant simulation run, North America would even have to give up its position as food exporter; Latin America would then take over this function to a considerable degree.

25. Stabilisation of the world market price at a relatively high level thus enables gradual improvement of the food supply of poor coun-

tries (measured in average food consumption per capita). The extent of hunger, however, is not very sensitive to such a policy. It is true that hunger decreases somewhat as a higher international price level is pursued, but there is no chance of its being eliminated (compare in Table 3, columns 4 and 5, respectively columns 10 and 11). This is due to the contrasting influences which the food price level has on the purchasing power in the poor countries of the urban population on the one hand, and of the rural population on the other hand. High prices favour the farmers (and therefore their consumption), but operate to the disadvantage of non-agricultural consumers, and vice versa.

Regulation of the world market, therefore, notwithstanding its positive effects, is not likely to render food aid unnecessary. As we have ascertained earlier, hunger is caused above all by the unequal distribution of income within the developing countries. And this cause can hardly be eliminated with the aid of the international policy measures introduced above.

All the same, the hunger that prevails in the world cannot be ignored. A world market policy combined with large-scale food aid could alleviate hunger and also stimulate the development of food production in the poor countries (Table 3, columns 6 and 12). MOIRA has shown that purchases on behalf of food transfers can both support and obstruct the world market price policy, dependent on the demand and supply position. Under conditions of rapid economic growth the extra demand for food is more likely to oblige the rich nations to reduce their consumption. Under conditions of moderate growth, food aid will reduce the necessity for rich countries to limit their production growth (see paragraph 24).

26. As an alternative to deliberate influencing of world market prices,

MOIRA was used to check the effect of a liberalisation of international trade in basic foods. It is assumed that the rich countries in particular would no longer protect their domestic food markets. Under this assumption, hunger in the period 1975-2010 will average 10-15 percent more than if policies remain unchanged. Production in the developing countries will grow more slowly than if policies remain unchanged;

in the rich countries it will grow more rapidly. North America's export position will be strengthened; on the other hand, the import dependence of the South Asian countries will be increased. Liberalisation of trade policies therefore does not appear to favour agriculture and food supply in the economically less-developed countries.

The Role of the Rich Countries with regard to World Food Supply

27. The influence which the rich countries are able to bring to bear to safeguard the world food supply is based on the (direct and indirect) relations between the development of the production and consumption of food in the industrialised nations on the one hand, and that in the developing countries on the other hand. However, the capacity of rich countries to favourably influence the structure of world food supply in this way proves to be fairly restricted. This is chiefly due to the preponderant role that is to be played by the national policies of the developing countries with regard to agricultural development and income distribution. According to MOIRA, a deliberate change of income distribution in these countries in favour of the agricultural sector will encourage production growth and reduce the import dependence of countries in South Asia in particular (Table 3, column 7). However, this does not reduce the extent of hunger. A lowering of hunger will be realized only if income differences within both the urban and the rural populations can be reduced (see paragraph 19 above). Here, too, primary responsibility lies with the developing countries themselves.

Nevertheless, the rich nations should be expected to do everything within their power to create international conditions which will be conducive to the improvement of the food situation in the poor countries. Technical and financial development aid in the agricultural sphere can only achieve its full effect if the desired production growth does not peter out because of lack of purchasing power. This applies not only on the regional level but certainly also on the international level. For this reason, a purposeful world market price policy - effectuated by the rich countries - will form an essential complement to the increasing international effort that is being made to improve the food supply of the poor countries.

28. The international policy for agriculture and food supply advocated above requires that the rich countries significantly reorient their agricultural policies. The rivalry between the economic blocs within the western world (i.e. between North America and the Common Market) with regard to agricultural policies will have to make place for a common effort towards a global food supply policy. In pursuing their national agricultural policies, the rich countries will have to make allowances for the targets of this international policy. The desire to stabilise world market prices at a fairly high level entails that the rich nations should take more effort to adapt the volume of their own food production (and if necessary also their own consumption) to the international demand and supply situation. A more flexible agricultural policy is then necessary, as the OECD has ascertained (OECD, 1975).[7] With this purpose in mind, the rich countries will have to extend and complement the instruments of their agricultural policies so that both national and international targets can be realised. As far as the European Common Market is concerned, this would signify that efficient measures by which to influence the size of production must be given greater significance in the instrument arsenal. In view of the international interests which this would serve, it should be possible to overcome any technical difficulties.

29. The conditions under which regulation of the world market would be possible are not likely to be fulfilled from one day to the next. All too frequently, in fact, international cooperation strands on the priority of national interests. It is to be hoped that the 'Food for a Doubling World Population' study will be able to support the efforts to put international economic relations at the service of a target transcending narrow national interests, in this case: sufficient food for all.

Table 3: Development of food production and consumption (in cons.prot.) and of hunger in the world during 1975-2010 under alternative assumptions regarding the policies of rich countries (results of MOIRA-simulations).

I. Relatively high income growth outside the agricultural sector

		(1) Unchanged policy: standard run				(2) Mitigation of food consumption in rich countries				(3) Food aid on a large scale by the rich countries			
	1975	1980	1990	2000	2010	1980	1990	2000	2010	1980	1990	2000	2010
(a) Total agricultural production (10^8 kg.cons.prot.)													
North America	520	600	858	1100	1210	600	727	780	780	595	881	1027	1300
European Community	181	217	300	365	407	218	268	310	326	220	296	382	451
Latin America	246	319	460	640	946	290	424	639	920	280	424	641	923
Tropical Africa	91	106	1[illegible]7	227	355	95	148	163	219	95	150	210	305
Middle East	75	100	13[illegible]	198	250	100	130	221	268	100	120	220	283
Southern Asia	320	389	452	593	641	398	320	552	382	410	481	645	750
WORLD	2560	3067	4178	5430	6595	2950	3949	4810	5321	2964	4220	5354	6674
(b) Food consumption (fish incl.) per caput (kg.cons.prot.)													
North America	120	131	148	163	175	125	133	133	98	126	149	163	175
European Community	104	110	128	142	155	105	113	115	84	106	123	140	153
Latin America	48	53	64	77	91	52	62	76	92	52	64	78	91
Tropical Africa	27	29	35	42	53	27	32	36	41	29	36	41	49
Middle East	38	46	52	69	74	45	55	63	81	48	55	69	82
Southern Asia	25	27	27	29	28	26	25	25	20	27	29	32	33
WORLD	50	54	61	68	73	53	58	63	60	53	62	70	75
(c) Self-sufficiency-ratio for food in cons.prot.													
North America	150	150	175	190	185	155	164	168	205	163	178	179	194
European Community	61	65	74	77	76	69	75	83	114	69	76	82	85
Latin America	115	115	105	102	101	108	102	101	96	107	100	99	100
Tropical Africa	110	105	99	96	94	100	99	76	73	95	90	90	88
Middle East	85	80	78	67	60	80	68	72	60	85	70	70	60
Southern Asia	95	98	90	89	86	104	91	97	59	104	93	90	83
(d) Price indicator world food market ('1965'=100)	77	307	232	316	442	397	218	24	-20	702	690	561	706

	(1) 1975	(1) 2010	(1) yearly average	(2) in 2010	(2) yearly av. 1975-2010	(3) in 2010	(3) yearly av. 1975-2010
(e) Hunger: million people below minimum food standard (mln.)							
gross	370	1525	565	2880	70[illegible]	1170	635
net	-	-	-	-	-	0	50
Total food deficit of hungry people (10^8kg.cons.prot.)							
gross	31	127	47	240	59	97	53
net	-	-	-	-	-	0	4

Table 3: (continued)

I. Relatively high income growth outside the agricultural sector

	(4) Stabilization of world market price around a low level (100)				(5) Stabilization of world market price around a relatively high level (300)			
	1980	1990	2000	2010	1980	1990	2000	2010
(a) Total agricultural production (10^8 kg.cons.prot.)								
North America	595	775	902	1110	605	807	968	1200
European Community	216	216	323	366	216	271	339	397
Latin America	293	440	662	948	295	441	663	970
Tropical Africa	103	164	226	328	106	165	230	332
Middle East	100	125	221	280	100	126	215	284
Southern Asia	386	410	552	596	389	433	587	662
WORLD	3021	4061	5100	6208	3026	4129	5260	6434
(b) Food consumption (fish incl.) per caput (kg.cons.prot.)								
North America	125	136	147	151	131	145	155	168
European Community	106	117	127	130	109	123	133	148
Latin America	52	63	78	91	52	63	78	91
Tropical Africa	29	35	40	48	29	36	42	51
Middle East	49	54	66	80	48	52	72	75
Southern Asia	27	26	27	26	27	27	28	28
WORLD	53	59	66	69	54	60	68	72
(c) Self-sufficiency-ratio for food in cons.prot.								
North America	170	173	175	190	163	167	175	187
European Community	70	70	76	81	67	70	77	78
Latin America	110	105	103	101	110	105	103	101
Tropical Africa	105	103	100	96	104	100	95	92
Middle East	70	73	70	64	86	62	64	69
Southern Asia	97	86	90	84	99	92	92	86
(d) Price indicator world food market ('1965'=100)	127	112	78	135	294	337	314	340
(e) Hunger: million people below minimum food standard (min.)	in 2010		yearly av. 1975-2010		in 2010		yearly av. 1975-2010	
gross	1440		600		1320		545	
net	-		-		-		-	
Total food deficit of hungry people (10^8 kg.cons.prot.)								
gross	120		50		110		45	
net	-		-		-		-	

Table 3: (continued)

I. Relatively high income growth outside the agricultural sector

	(6) Food aid + price stabilization around a relatively high level(300) 1980	1990	2000	2010	(7) Food aid + price stab. high level + decreasing income differences in city + higher incomepos. agriculture 1980	1990	2000	2010
(a) Total agricultural production (10^8 kg.cons.prot.)								
North America	619	760	918	1124	627	838	627	1171
European Community	220	275	349	403	220	279	352	398
Latin America	286	425	641	920	297	442	606	952
Tropical Africa	95	150	210	305	104	164	226	321
Middle East	100	130	200	283	100	123	210	290
Southern Asia	410	431		705	407	465	662	750
WORLD	2964	4043	5179	6339	3029	4211	5331	6467
(b) Food consumption (fish incl.) per caput (kg.cons.prot.)								
North America	120	141	147	153	133	146	162	168
European Community	100	119	125	131	112	123	136	141
Latin America	54	63	77	91	53	66	82	100
Tropical Africa	30	34	40	47	28	34	38	44
Middle East	49	56	67	80	50	57	75	84
Southern Asia	28	27	30	30	27	28	31	31
WORLD		60	66	71	54	61	68	72
(c) Self-sufficiency-ratio for food in cons.prot.								
North America	160	164	176	190	155	172	172	181
European Community	72	73	84	89	65	72	78	82
Latin America	105	101	101	101	108	101	99	96
Tropical Africa	94	96	92	92	105	104	105	103
Middle East	80	70	70	65	80	65	68	63
Southern Asia	98	88	88	87	103	91	96	90
(d) Price indicator world food market ('1965'=100)	500	361	317	371	425	352	387	398
(e) Hunger: million people below minimum food standard (mln.)	in 2010		yearly av. 1975-2010		in 2010		yearly av. 1975-2010	
gross	1320		590		470		294	
net	0		30		0		12	
Total food deficit of hungry people (10^8 kg.cons.prot.)								
gross	110		49		39		25	
net	0		3		0		1	

Table 3: (continued)

II. Moderate income growth outside the agricultural sector

	(8) Unchanged policy standard run					(9) Food aid on a large scale by the rich countries				(10) Stabilization of world market price around a low level (100)			
	1975	1980	1990	2000	2010	1980	1990	2000	2010	1980	1990	2000	2010
(a) Total agricultural production (10^8 kg.cons.prot.)													
North America	517	534	699	793	871	600	689	722	884	560	630	560	620
European Community	177	210	262	305	325	219	250	304	350	209	232	260	307
Latin America	246	318	449	574	781	290	420	620	876	294	431	634	886
Tropical Africa	92	107	110	159	214	95	130	160	200	105	137	140	208
Middle East	63	88	114	137	115	100	110	184	208	100	110	145	155
Southern Asia	300	375	421	428	497	398	401	410	450	375	400	420	475
WORLD	2560	2933	3604	4202	5105	2886	3585	4200	4986	2884	3530	3870	4721
(b) Food consumption (fish incl.) per caput (kg.cons.prot.)													
North America	119	122	130	137	141	125	130	136	140	122	129	136	134
European Community	103	108	116	121	128	105	114	120	126	107	113	117	118
Latin America	47	49	53	53	56	50	51	54	57	48	51	52	57
Tropical Africa	26	27	27	27	30	27	30	30	31	27	28	27	29
Middle East	40	42	45	46	46	44	44	48	49	44	41	44	46
Southern Asia	26	27	24	22	22	27	26	25	25	26	24	22	23
WORLD	50	51	52	53	54	52	53	54	55	51	52	52	53
(c) Self-sufficiency-ratio for food in cons.prot.													
North America	150	144	161	163	161	160	159	150	163	162	146	111	127
European Community	58	65	71	76	74	69	72	76	80	65	65	65	75
Latin America	117	125	128	132	132	114	123	139	151	116	127	149	152
Tropical Africa	112	111	88	102	100	98	96	94	90	111	107	100	100
Middle East	75	79	72	68	42	80	75	86	77	89	79	67	60
Southern Asia	95	97	95	85	84	101	87	73	62	96	90	82	75
(d) Price indicator world food market ('1965'=100)	76	20	-17	70	24	331	104	126	121	5	56	98	147
(e) Hunger: million people below minimum food standard (mln.)	1975	2010		yearly average		in 2010		yearly av. 1975-2010		in 2010		yearly av. 1975-2010	
gross	370	1600		820		2040		837		1320		723	
net	-	-		-		0		18		-		-	
Total food deficit of hungry people (10^8kg.cons.prot.)													
gross	31	133		68		170		70		110		60	
net	-	-		-		0		2		-		-	

Table 3: (continued)

II. Moderate income growth outside the agricultural sector

	(11) Stabilization of world market price around a relatively high level (300) 1980	1990	2000	2010	(12) Food aid + price stabilization around a relatively high level (300) 1980	1990	2000	2010
(a) Total agricultural production (10^8 kg.cons.prot.)								
North America	517	530	533	487	580	598	586	512
European Community	202	236	289	310	218	243	297	330
Latin America	294	436	649	923	285	422	628	990
Tropical Africa	106	163	221	315	95	134	184	255
Middle East	90	127	216	258	100	105	174	232
Southern Asia	379	410	571	650	400	420	550	660
WORLD	2784	3476	4240	4980	2875	3489	4422	4960
(b) Food consumption (fish incl.) per caput (kg.cons.prot.)								
North America	122	129	135	139	122	130	135	139
European Community	103	110	116	123	102	110	116	122
Latin America	48	52	56	59	50	52	55	58
Tropical Africa	27	32	35	38	27	30	31	33
Middle East	44	42	48	49	44	43	47	49
Southern Asia	26	24	26	25	27	25	26	27
WORLD	51	52	54	56	51	52	54	56
(c) Self-sufficiency-ratio for food in cons.prot.								
North America	139	122	112	93	160	139	123	100
European Community	63	68	75	73	72	70	77	79
Latin America	118	126	140	154	111	129	138	150
Tropical Africa	112	112	113	117	97	98	103	109
Middle East	86	80	91	96	85	95	85	86
Southern Asia	99	95	98	96	101	95	93	90
(d) Price indicator world food market ('1965'=100)	140	305	306	295	340	307	313	284
(e) Hunger: million people below minimum food standard (mln.)	in 2010		yearly av. 1975-2010		in 2010		yearly av. 1975-2010	
gross	1320		600		1610		723	
net	-		-		0		21	
Total food deficit of hungry people (10^8 kg.cons.prot.)								
gross	110		50		134		60	
net	-		-		0		2	

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Summary of the Discussion on MOIRA

(A Model of International Relations in Agriculture)

Edited by Gerhart Bruckmann

GENERAL DEBATE

In the general debate, Niaz raised the question of what was the main objective of the model, and what purpose should it serve, especially as a number of other institutions (e.g. FAO, USDA) have recently engaged in similar work.

Linnemann replied that the main purpose of the study was to integrate and to deepen the already existing insights into the mechanisms that govern the international relations in agriculture. Beyond the scientific interest, the members of the groups were also led by moral motives to contribute toward a solution to the world food problem. If the notion of "triage" must be absolutely rejected, and if it can be shown that there is no absolute scarcity of food, but only maldistribution, it is worth investigating the results of possible solutions.

MAXIMUM FOOD PRODUCTION

A discussion followed the presentation by van Heemst, "The Absolute Maximum Food Production of the World". In particular, Etienne opined that the upper limits must be considered too high for a number of countries, often owing to given water constraints. This was also underlined by Levis. On the other hand, it might have been worthwhile to have taken into account ground water potentials as a source for irrigation; this might play a major role in countries such as India, Bangladesh, or China. Niaz pointed out that other limits are set by the area needed for non-food crops, and by the increasing land use for nonagricultural purposes. Weber underlined the need to consider who would have to assume the expense of expanding agricultural areas. In this connection, it must be tacitly assumed that all the necessary fertilizer must be provided without any restriction on available land. Meadows inquired whether land degradation was sufficiently considered in the model. Gallopin saw the need to differentiate between physical limits on one side, and limits owing to socio-political factors on the other side.

In reply, van Heemst claimed that a hundred years ago nobody would have believed it possible to raise yields from one ton per hectare to five tons per hectare, as it is done today. He stressed, however, that the main purpose of the computation was to find the asymptote for the production function to be used in the model. Fertilizer was not considered in this connection, as it appears elsewhere in the model as a limiting factor. The relation of food crops to nonfood crops was assumed constant, for the purpose of this study. Moreover, land degradation was not considered owing to a lack of data. This means that for the computation of the maximum food production, such management was assumed as to avoid land degradation. On the other hand, land that was susceptive for soil degradation was excluded anyway. Lack of water for irrigation was taken care of by considering zones of different fertility.

Rademaker proposed that not too much discussion time be devoted to this theoretical asymptote, which may be quite interesting but which plays only a minor role in the model. Etienne, supported by Bruckmann, said that he felt uneasy about this maximum food production concept inasfar as it might be easily mistaken by careless readers to be a goal readily attainable in the near future, and thus might be leading to a feeling of complacency.

POPULATION

As to the population projections used for the model (population being treated exogenously), Etienne wondered to what extent the most recent developments had been incorporated. He mentioned in particular the fact that population growth rates have begun to decline in some important Asian countries (e.g. South Korea, China, Taiwan, Sri Lanka, and some parts of India). Bottomley suggested that population should have been broken down to economically active and inactive population. Linnemann replied that it would have been difficult to distinguish between actively employed and total agricultural population. During seasonal peaks the whole family may be working, including members who at other times are working outside agriculture; at other times practically nobody may be working in agriculture. For other purposes, total agricultural population was needed anyway. The problem can be bypassed by assuming that all people in agriculture are available as a working force. A breakdown as suggested would not have added any precision. Population, being an exogenous variable, implies a given natural growth rate for both sectors taken together; the model limits itself to migrations between agricultural population and nonagricultural population. Parikh expressed doubts as to whether people actually migrate from agriculture to the cities for economic reasons, as reflected in the model; in most instances, they are economically worse off in the cities than they were in agriculture before they migrated. Linnemann admitted to the existence of meta-economic reasons; however, these reasons will be enhanced (or diminished) by economic factors.

CLIMATE

Kamrany raised the question of the climatic conditions. Whereas the model seems to assume constant conditions, he stressed that agricultural production may be much more dependent upon climatic fluctuations than upon price fluctuations. De Hoogh replied that the model does reflect climatic oscillations to a certain extent: in the model the oscillations observed in the seven year period from 1965 to 1971 were extrapolated over the thirty-five year period of the investigation. Bruckmann observed that this seven year period does not include a period of major crop failure in two successive years, as it happened in 1963-64 and again in 1972-73. He suggested that a "standard feasible disturbance" be defined and introduced deliberately into the model, and that trial runs be made to study the impact of such a standard feasible disturbance (or multiples thereof) at different periods of time on numerical outcomes of the model.

CONSUMABLE PROTEIN

A lengthy debate developed around the fact that the model reduces all food to one standardized commodity, namely consumable protein. Parikh asked how different price movements for different commodities and changes in consumer behavior could be reflected in the model if it only exhibits one commodity. Niaz stressed that a reduction to consumable protein obscures the fact that a lower or higher part of it may be used for livestock production (or for non-food purposes). On the other hand, he did not see how noncereals (such as fruits and vegetables) could be transformed into consumable protein in a meaningful manner. If these commodities were left out, the model would not reflect sufficiently well the agricultural development potential. The model assumption that cereal crops will account constantly for 65 percent of the cultivated area must be seriously doubted. Also, the expected development of the presently non-irrigated areas should be discussed in more detail. Furthermore, it appears doubtful whether "malnutrition" can be properly assessed by an analysis of consumable protein only.

Weber believed that the reduction to one standard cereal leads one to neglect the importance of local climatic conditions that would allow production increases of different cereals only in different degrees. Gallopin, too, considered it important to split the calculations into different crops that are differently adapted for different regions. If local conditions could be properly taken care of, this might yield higher production increases than the model reveals.

In reply, Linnemann stressed first that consumable proteins should not be confused with proteins actually consumed by man. Van Heemst claimed that most of the local differences can be taken care of sufficiently well by the proper combination of consumable protein (as derived from the production of dry matter) and productivity of it for human consumption. "Consumable protein" does not stand for a particular cereal, nor for a standard cereal; it is a standard crop that has the properties of a cereal crop. Keyzer added (in reply to a written inquiry) that the model does not aim at reflecting differentiated price movements for such commodities as coffee, rubber, or cloth. In two later stages, food and nonfood agricultural products might be explicitly disconnected in the model.

PRODUCTION FUNCTION

Kulikowski raised the general question of whether or not the same results could have been obtained separately by using a much simpler production function, such as the Cobb-Douglas function for the agricultural and the nonagricultural sector. From whatever goal function one assumes, one can derive the proper allocation between capital and labor. However, there seems to exist an important time lag in agricultural investments that can be used for several years. For this problem, and for many similar ones, there exist standard economic and econometric procedures. What was the purpose of deviating from these procedures? Linnemann replied that the reasons for the choice of a particular production function were both of a theoretical nature (to allow for diminishing returns) and of a practical nature (to exhibit certain statistical properties).

CAPITAL

Keyzer added that capital appears as current input for statistical reasons and also because capital used was calculated from production realized. In reply to Gallopin's inquiry as to what extent technical progress has been incorporated in the model, Linnemann stated that embodied technical progress is reflected by the variable C in a rather complicated way.

Several speakers raised the question of to what extent it is justified to reflect agricultural investment by the number of tractors. Gallopin underlined that, because of the strong correlation between tractors and fertilizer, one can be used as an indicator of the other. Linnemann stressed that the number of tractors was used only once in the cross-sectional estimation; there indeed, it has been assumed that the number of tractors is a reliable indicator of the level of mechanization or capitalization of agriculture. This is not to say that only tractors are used. Many other things are used as well, but all these other things are supposed to move parallel to either the number of tractors, or the amount of fertilizer used.

DIMINISHING RETURNS

As for diminishing returns, Niaz opined that production potentialities in many countries (e.g. Iran) by far exceed what the model suggests. Richardson advised that one should not be misled by technical coefficients. If, for instance, the average yield in Japan is four times the average yield in India, one cannot conclude immediately that production figures can be quickly quadrupled in India. If the model is slow in that respect, it reflects justly the political, economic and organizational mechanisms determining those differences. De Hoogh stated that there is historical evidence that agricultural production never exceeded a growth rate of 4 percent. So, to assume a growth rate of more than 3 percent in South Asia already means a fast development. Of course, with a population growth rate of more than

2 percent, there does not remain a high growth rate of food production per capita.

Gallopin expressed great interest in the fact that the model does not reflect diminishing returns form the use of fertilizer, in other words, that production depends on the input of fertilizer in a linear way. Parikh also doubted this, adding that experiments have been carried out in India on a large scale, showing that (by changing over to other varieties) one can achieve high production increases without any additional use of fertilizer. In reply, Linnemann explained why the linear relation seems justified: historical analyses show that diminishing returns always were upset by other technological advances, resulting in a (quasi-) linear envelope curve. Ceteris paribus, there certainly would be diminishing returns from the input of fertilizers, but the ceteris paribus clause simply is not given. On the other hand, overall input of capital is--in reality and in the model--subject to diminishing returns, as the marginal productivity of capital is decreasing rapidly. Waelbroeck admitted that on a macro-economic level, linear dependence of production from fertilizer input may be justified. The individual farmer, however, certainly bases his input decision on an awareness of the diminishing return on his yield of fertilizer input. Linnemann claimed that these facts are taken into consideration by certain constraints within the model. Keyzer agreed that in principle a cross-section estimate is wrong to show the behavior at a certain moment. However, the long-term function is an envelope of the short-term function.

When taking his production decision, the farmer is confronted with a short-run production function which shows returns that are more strongly diminishing than in the long-run production function. This is caused by the fact that in the short-run some means of production are fixed and the rate of change in technique is limited.

In the model, this is reflected by limits on the short-run rate of substitution between capital and labor, on the growth rate of production by a distributed lag mechanism and by the fact that labor supply is given in the short-run.

PRICE MECHANISM

As for the functioning of the price mechanism, Kamrany raised the question of whether the model reflects sufficiently well the fact that large parts of this world are not subject to it: in all socialist countries, production decisions are being made independent of changes in world market prices and the same is true for subsistence farming worldwide. Keyzer replied that it is essential to distinguish between the market mechanism in general and the role that price plays in different countries. The internal price may well be regulated within a country and in the model, an agricultural sector may well be completely insensitive to price changes because of its isolation; but as for exports and imports, the same country would still depend on the world market price. On the contrary, it is one of the main features of the model to reflect these possible differences of agricultural prices on the different systems.

Bruckmann pointed out that there may be important areas in which agricultural production may depend negatively from price. A story--true or not--is told about a U.N. advisor who showed the people of some developing nation how to increase their yield three-fold; returning to them the next year, he found them playing kahala and their fields idle. They celebrated him as the man who enabled them to work only one year out of three, being able to play kahala the other two years. Also in industrialized nations a large part of the agricultural population may base its production decisions on "expected sufficient income"; when the price of a product goes down, the farmer produces more of it to make up for the loss he otherwise has to incur. On second thought, however, while being true on the micro-level, it may not be true on the macro-level: the fall in prices may enhance the movement of agricultural population to the cities, and if this movement exceeds the production increase of the farmers who decide to stay, the overall result may be a decrease in production.

Parikh agreed with Bruckmann; in India the marketable surplus goes up if prices go down. Kamrany pointed out that the same experience was observed in the U.S.A.; the big surpluses in the 1950s resulted from the industrial farmer's attempt to offset the decrease in prices by an increase in production. Etienne added that in many societies certain foodstuffs are not being sold on the market. If the supply of millet in some African societies exceeds consumption for food purposes, the excess is simply being used for more beer parties.

Keyzer and Sanderson stressed the need to differentiate between short- and long-term views. In the short term, the reactions of the individual farmer may well be of the kind as described by Bruckmann, Parikh and Etienne.

In the long term, however, higher prices for food will enable more investment, better irrigation projects, and the like, than would have been feasible otherwise. The other way around, Sanderson inquired about the low elasticity exhibited in the model. How can a tripling of food prices result in only such a small increase in production? Furthermore, this tripling of price leads in South Asia only to a marginal improvement of the availability of food, but not to a substantial improvement of the distribution. Does one really have to resort to a complete revamping of the world food economy in order to solve the internal distribution problem of South Asia? Obviously, the most straightforward approach to the problem would be a price policy in South Asia that would lead to a more equitable distribution of food. In this case, one also would not have to go to a tripling of prices. The reasoning seems to be that most of the hunger is in rural areas because most of the population is in rural areas. But by the year 2000 this may have changed, as people are migrating constantly into the cities. The urban food problem is becoming more and more important in South Asia. So by the year 2000, a high price policy may greatly aggravate the problem in the cities.

In reply, de Hoogh stated first that the price shown is the world market price, not the internal price of, for example, India, and secondly, that production does not only change as a result of the price. Total agricultural population, on a world level, is still increasing. In spite of the outflow of labor from agriculture, it appears that the number of people in agriculture is increasing during the forecasting period of the model. One of the reasons why the production is going up is the increasing labor force. The relative level, therefore, must not be seen as a consequence of prices only. At least in industrialized nations, farmers on the whole will certainly react positively to price changes; this is at least the assumption of the model.

Kamrany wished that the model would have been able to exhibit a comparison between a development owing to market forces and a possible development in which market forces were excluded as a factor that determines production. De Hoogh replied that to do this, a distinct mechanism would have to be spelled out as to how to determine world production without prices. Kamrany suggested that this could be done by extrapolating the potential production in dependence of the physical resources of the respective country.

In summarizing, de Hoogh defended the model's assumption that farmers, at least in the developed countries, react positively to price increases. However, price increases for food induce an increase in food consumption by the farming sector. So a perverse reaction of net supply on a price increase is possible.

Batteke claimed that a serious shortcoming of the model was the fact that government interventions in the form of taxes, subsidies and the like are not explicitly considered, as they are certainly instrumental in influencing farmers' decisions. Linnemann replied that keeping domestic prices separate from the world trade market price allows one to subsume a substantial part of government financial interventions. Keyzer added that prices are being estimated from the model as shadow prices.

EDUCATION

Millendorfer inquired to what extent the production functions used reflect differences in the educational level of a population. Linnemann answered that the catch variable "capital" is thought to comprise any investments, including any expenditures on education.

POPULATION PRESSURE

Etienne challenged the assumption that population pressure leads to increased production.

CENTRALIZED ECONOMICS

Kulikowski stated that the model did not seem to reflect properly the mechanisms at work in centrally-governed economies. By the mechanisms available to them, they are able to fare far better than the model suggests. Linnemann replied that he and his team are fully aware that the centrally-governed economies were treated rather crudely, and he welcomed whatever information will be furnished.

HUNGER

Niaz raised the question of to what extent "hunger" is mainly the consequence of uneven distribution, as stated in the model, and to what extent it is truly deficiency in absolute quantity. Parikh wondered why, in the model, hunger increases when the price for food decreases. De Hoogh replied that this is because with the decreasing price for agricultural products, agricultural income goes down; this more than upsets the benevolent effects of lower food prices for the nonagricultural consumer. De Haen suggested including explicitly in the model some relation between the nutritional level and labor productivity, for many parts of the world. De Hoogh replied that this link certainly exists and it could also be incorporated in the model without difficulty; however, data on the form of this link are missing. As for synthetic food, de Hoogh stated that in the modelers' opinion, synthetic food will not contribute much to the real problem of hunger in the world, for the following reasons: hunger was mainly a lack of purchasing power, and the production of synthetic food was likely to be realized in the industrialized nations first. There is no reason to believe that that form of food production will make it easier to eliminate hunger in the world. Hence, the production of synthetic food was not considered in the model.

BUFFER STOCKS

Keyzer underlined again the assumption of the model that the buffer stock to be established by the developed countries would not be an object of speculation; on the contrary, it would have to be handled in an exact way so as to offset speculation. Parikh inquired whether it would not make more sense if a country such as India would establish its own stock, to be independent from international price fluctutations. Keyzer admitted that keeping national stocks certainly is a meaningful policy, but this policy apparently has hitherto failed to cope sufficiently with fluctuations. Therefore, an international buffer stock is proposed.

SUMMARIZING CRITIQUE

Richardson asked to what extent can we justify the assumption that the parameters derived from an analysis of the period 1965-71 will remain valid for the entire forecasting period, that is up to 2010? Keyzer replied that 1965-71 served as a calibration period for estimating the parameters and their possible variations as well as the model relations including the the shadow prices for the base period.

Etienne stressed the importance of being aware of the enormous margin of error of most agricultural data.

Meadows inquired how current government policies to maintain agricultural/nonagricultural price balance were obtained. Keyzer replied that the assumptions were based upon the information gained in numerous discussions with experts from the Common Market, the World Bank, and from developing countries. Meadows pointed out that the model rests on the (tacit) assumption that it is easier to change the world economic order than the world social institutions which contribute to population growth. The overall goal should be to change both! Sanderson, too, questioned whether it would be easier to change the world economic order than to change national policies. De Hoogh clarified that at no point is it claimed that it would be easy to change the world economic order; all the model strives for is to show what the effect of such a change would be.

Waelbroeck said that the most important question to be asked of any model is whether it includes all the relevant mechanisms. Now the market mechanism may prove relevant for only a fairly small part of the total world food production; a much higher part may be independent of the market price inasfar as food production may depend on government decisons on irrigation, education or farmers, and so forth. Furthermore, it may not be true that price elasticity works only via the income distribution. In the United States, for instance, we certainly have a direct price elasticity of demand; if prices go up, demand will go down, much more strongly than is shown in the model.

In reply, de Hoogh stressed again the difference between the market price and the shadow price. This shadow price, as originally calculated from the base period, expresses both the market price and also all corrections owing to government interventions influencing agriculture. This seems to be the only way to avoid having to consider explicitly the huge number of government measures existing in different countries.

Modelling of Production, Utility Structure, Process and Technological Change†

Roman Kulikowski

ABSTRACT

The paper deals with modelling of complex development systems including production, consumption and environment. The production subsystem consists of n given sectors described by CES production functions. The decentralized decision system allocates the GNP among the given spheres of activity including investments, consumption, government expenditures, and environment, in such a way that the given utility function attains the maximum value. The utility function changes along with GNP per capita. Then the price indices can be computed. The price changes result in a change in the production function technological coefficients. The future projections of development processes can be derived in the iterative form. All the model parameters can be derived from historical data.

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A World Agricultural Model: An Input-Output Research Proposal

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INTRODUCTION

The research is based on some 300-plus national input-output tables for some 80 different countries. The data were collected by the Input-Output Research Group at the University of Bradford; the countries for which we have input-output matrices are listed in Table 1. These tables have been aggregated into the 10 by 10 standard format as shown for Zambia in Table 2. We hold other matrices which have not yet been so treated. The money flows shown in Table 2 have also been translated into tables giving percentages of gross output in each element of the matrix, technical coefficients and the Leontief inverse. All are stored on magnetic files in the University of Bradford computer and can be easily printed out in the form of Tables A1, A2, and A3 for Zambia in Appendix A.

We first propose to increase the number of these tables so as to include countries that had previously been omitted; they will then comprise our initial world model. Second, we will construct an international trade matrix so as to connect the individual matrices for each country described above in the manner outlined in Table 3. Third, we will expand both the individual country and the world trade matrices to incorporate the 21 by 21 inter-industry flow matrix given in Table 4. This last translates the world model which will be constructed in the first and second stages into a detailed agricultural model with considerable disaggregation of the agricultural and chemical sectors. Fourth, we will apply the model to the kinds of uses listed in Section IV of this proposal.

All four of the stages outlined above will be expressed in terms of a 1970 base year model and a 1980 projected model, although we may be able later to extend the projections to 1990. We therefore deal with each of these stages in turn.

I. CONSTRUCTION OF INDIVIDUAL INTER-INDUSTRY FLOW MATRICES FOR 1970 AND 1980 TO COVER THE WORLD

These must comprise both domestic and gross product inter-industry flow matrices for 1970 and 1980. We chose these dates because they cover the FAO's *Agricultural Commodity Projections 1970-1980* which form the basis of the agricultural model discussed below. We hear that these projections have been updated to 1990; if this is so, our model will run to that later.

Table 1. List of input-output tables held at the University of Bradford, UK.

COUNTRY	YEARS
Algeria	1954, 1957, 1963
Antigua	1963
Argentina	1950*, 1953*, 1959, 1960
Australia	1946-47, 1943-54, 1958-59*, 1962-63*
Austria	1964*
Belgium	1953, 1958, 1959, 1965*
Bolivia	1958
Brazil	1959
Bulgaria	1963
Cambodia	1966*
Cameroun	1959
Canada	1949*, 1961
Ceylon (Sri Lanka)	1963*, 1965, 1968, 1970
Colombia	1953, 1968
Costa Rica	1957
Cyprus	1954*, 1957*
Czechoslovakia	1962*
Denmark	1946, 1947*, 1948*, 1949, 1953, 1958, 1966*
Ecuador	1963
Egypt	1954*
Fiji	1970*, 1971*
Finland	1956*, 1959*, 1963, 1965
France	
East Germany	1956*, 1959*
West Germany	1950, 1953, 1954*, 1955*, 1956*, 1957*, 1958*, 1959*, 1960*, 1961*, 1962*, 1963*, 1964*, 1965*, 1966*, 1967*, 1970
Ghana	1960*
Greece	1954*, 1958*, 1960*, 1966
Guyana	1959*
Hungary	1957, 1959, 1964, 1965, 1966, 1967, 1968, 1971
India	1951-52, 1953-54, 1955-56, 1959, 1960-61*, 1964-65
Indonesia	1969
Iran	1965*
Iraq	1960*, 1961*, 1962*, 1963*, 1967
Ireland	1956*, 1960*, 1964*, 1968
Israel	1958, 1968*-69*
Italy	1950, 1953, 1959*, 1965, 1967*, 1969*, 1970
Ivory Coast	1958, 1960, 1962, 1963
Jamaica	1958*, 1965, 1970, 1975
Japan	1951, 1954, 1965, 1970
Jordan	1964, 1967, 1969
Kenya	1967*
Korea	1960*, 1963, 1966*, 1968*, 1970*
Lebanon	1964
Mainland China	

Madagascar	1960
Malaysia	1960*, 1965
Mali	1959*
Malta	1961*
Mexico	1960*
Morocco	1958, 1960, 1964, 1965, 1966, 1969
Netherlands	1938, 1948, 1949, 1950, 1951, 1952, 1953, 1954, 1955, 1956*, 1957*, 1958, 1959, 1965*, 1970
New Zealand	1952-53*, 1954-55*, 1959-60*, 1960-61, 1961-62, 1962-63, 1963-64, 1964-65
Nigeria	1959-60*
Northern Ireland	1963
Norway	1947*, 1948*, 1950*, 1954*, 1956, 1958, 1959*, 1964*
Pakistan	1954, 1960-61*, 1965, 1970, 1975, 1980, 1985
Peru	1968*
Philippines	1956*, 1961*, 1965
Poland	1957, 1967
Portugal	1959, 1964
Puerto Rico	1963
Rhodesia	1965*
Rwanda	1970
Senegal	1959*
Singapore	1967*
South Africa	1956-57
Spain	1954, 1955, 1956, 1957, 1958, 1962, 1965, 1966
Sudan	1961-62*
Sweden	1958, 1964*, 1968*
Syria	1956, 1958-60, 1963*, 1964-65
Taiwan	1954, 1961, 1964*, 1966, 1969
Tanganyika	1954, 1961*
Thailand	1954
Trinidad	1959*
Tunisia	1957*, 1960*, 1962*, 1964
Turkey	1963, 1967*, 1968
United Kingdom	1935*, 1948, 1954*, 1963*, 1968*, 1970
United States	1919*, 1929*, 1938*, 1947*, 1958, 1963
USSR	1959, 1966*
Virgin Islands	1968
Yugoslavia	1958, 1962*, 1964, 1966*, 1968*
Zaire	1957*
Zambia	1965*, 1966*, 1967*, 1969*

*Tables comprising both domestic and import matrices.

Table 2. Input-output table for Zambia, 1969 (in millions of Zambian Kwacha).

		1	2	3	4	5	6	7	8	9	10	Intermed. output	Final demand	Domestic	Exports	Gross output	Import column	Output
Agriculture	1	1.[illegible]	2.18	18.96	1.19	1.19	0.03	1.28	0.23	0.00	0.57	26.82	78.11	72.91	5.20	104.83	14.72	90.11
Mining	2	0.19	32.56	0.13	0.00	0.23	1.34	0.42	1.50	1.96	0.08	38.41	790.18	-30.02	820.20	828.59	5.62	822.97
Foodstuffs	3	1.24	0.50	12.14	0.00	0.55	0.00	0.48	0.00	0.00	10.50	25.41	117.94	116.84	1.10	01.54	37.52	24.02
Textiles	4	1.18	0.14	0.89	8.92	0.03	0.01	0.30	0.03	0.00	2.07	13.57	47.97	47.42	0.55	01.54	37.52	24.02
Chemicals	5	8.29	14.35	6.43	0.64	13.12	1.52	4.43	4.70	0.40	19.84	73.72	30.05	29.68	0.37	103.77	65.89	37.88
Metal Manufg.	6	1.98	15.14	2.12	0.30	0.48	11.90	6.08	31.55	2.04	14.13	85.72	136.86	125.16	11.70	222.58	180.16	42.42
Unspecified Manufg.	7	2.24	26.20	2.10	0.88	0.96	2.22	11.75	6.70	0.00	27.39	80.44	16.99	15.92	1.07	97.43	24.86	72.57
Construction	8	0.82	26.24	12.22	0.52	0.61	0.93	10.68	18.74	0.27	16.11	87.14	77.43	77.43	0.00	164.57	3.58	160.99
Energy	9	1.20	16.81	0.97	0.11	0.24	0.42	4.41	0.57	13.86	9.80	53.39	3.68	3.68	0.00	57.07	18.83	38.24
Services	10	2.72	72.73	13.07	2.13	4.72	6.33	28.30	16.45	0.55	110.85	257.85	327.41	304.81	22.60	585.26	47.25	538.01
Intermed. Input	11	20.95	206.85	69.03	14.69	22.13	24.70	68.13	80.47	24.08	211.34							
Value Added	12	69.16	616.12	46.82	9.33	15.75	17.72	4.44	80.52	14.16	326.67							
Total Input	13	90.11	822.97	115.85	24.02	37.88	42.42	72.57	160.99	38.24	538.01							
Import Row	14	9.28	27.97	16.89	9.43	11.51	6.06	20.13	37.11	19.23	34.79							

Total Output 1943.06

Table 3. Three-country international trade matrix.

Exports / Imports		Country A			Country B			Country C			FINAL DEMAND			
		1	2	3	1	2	3	1	2	3	A		B	C
A	1	10			2						100			
	2	20									20			
	3	10									20			
B	1	10			0						10			
	2				3						10			
	3	10			3						10			
C	1										10			
	2	10			4						10			
	3	10									10			
VA*		20			8									
Total		100			20						200			

*Value Added.

Table 4. Expanded individual country standard matrix.

Inputs \ Outputs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22 Intermediate output	23 Domestic final demand	24 Export demand	25 Final demand for imports	26 Intermediate demand for imports	27 Additional irrigation demand	28 Additional land clearing demand	29 Additional afforestation	30 Total domestic output
1 Grains																														
2 Other arable crops																														
3 Non-food crops																														
4 Permanent crops																														
5 Livestock																														
6 *Forest products*																														
7 Fish																														
8 Nitrogen																														
9 Phosphates																														
10 Potash																														
11 Pesticides and fungicides																														
12 *Other chemicals*																														
13 Processed food																														
14 Mining																														
15 Clothing																														
16 Textiles																														
17 Metal manufacturing																														
18 *Unspecified manufacturing*																														
19 Construction																														
20 Energy																														
21 Services																														
22 Intermediate total																														
23 Value added																														
24 Total input																														
25 Grain land																														
26 Other arable land																														
27 Non food crop land																														
28 Permanent crop land																														
29 Pasture land																														
30 Forest land																														
31 Irrigated land																														
32 Potential cropping land																														
33 Potential pasture																														
34 Employment																														
35 Wages																														

There are parts of the globe which are not yet covered by our collection of tables, and gaps will remain even though the search goes on for more country tables. Therefore, a principle of analogy will have to be adduced in order to construct hypothetical tables for countries for which matrices do not yet exist. We have already grouped countries of similar economic structure, and will therefore take the average element coefficients for a particular group and assume that these hold for countries which would belong in that group but which do not yet have their own input-output data. Countries will be grouped according to per capita Gross Domestic Product (GDP), geographical location and climate, cultural affinity and the like. We have already carried out preliminary analysis along these lines for the World Employment Programme of the International Labour Office (ILO), but there appears to be considerable variance around co-efficient means. Nevertheless, we see no alternative to this approach of adding to the model those countries which do not yet have input-output tables. Perhaps we can console ourselves with the knowledge that we have tables covering most of the world's population, although many of these are more than ten years old and the data for China are speculative in composition. Nevertheless, our supposition remains that the model will give us the relative orders of magnitude for its different components and these will be revealing from a policy-making point of view. Ideally, base year 1970, GDP's divided by sector would be fed through the Leontief inverses of updated input-output tables where originals exist and through the foregoing hypothetical tables where they do not; certainly this will be the method for forecasting the 1980 or 1990 tables. GDP for 1980 or 1990 can be apportioned between the separate elements of final demand in accordance with the latest known distribution, or following a regression analysis of how these proportions change with changes in per capita GDP (i.e., sector income-elasticity of demands). In the case of the 1970 base year, we do know how value added is distributed along the rows in accordance with the data contained by country in the UN *Yearbook of National Accounts Statistics* or, to be more accurate, we can generally assign a value added (VA) figure to columns 1 and 2 separately, another figure to columns 4, 5, 6 and 7 in total, and yet another to columns 8, 9 and 10 in Table 2. Original proportions in the value added column can be retained where the 1970 figure straddles more than one column.

Apportioning the 1970 domestic and export GDPs from the *Yearbook of National Accounts* and processing the result through the supposed 1970 Leontief inverse may give a value added distribution along its row which does not accord with that found in the *Yearbook*. This will mean that either final demand has been wrongly distributed between sectors or that the inter-industry flow coefficients used are inaccurate. Serious discrepancy will mean that we will have to revise one or the other or both of these. If, for example, we assume that proportions between the sector value added and the column total remain as in the original table, then we can derive column totals and hence intermediate row totals as well as to accord with whatever distribution of final demand we may use. Thus the gross and intermediate row and column totals so derived will allow us to determine inter-industry flow coefficients by the RAS method; but this adds further elements of doubt to a method of coefficient prediction which is already frequently inaccurate.

If, however, reasonably convincing results can be adduced from one or the other of these methodologies, then we will be able to derive Uganda's input-output table, say, from its 1970 GDP. A final demand column vector can then be processed through an average, but still hypothetical Leontief inverse. Some very small states, such as those of the Eastern Caribbean, may be put together for the purposes of our model, with their aggregated GDPs being processed through the Leontief inverse for Antigua--the only state in this region for which we possess a table.

Then too, only the starred tables listed in Table 1 comprise both domestic and import matrices which are needed for a world trade model. We will therefore have to extend the principle of analogy to solving this problem. The starred tables within each group of countries with similar economic structures will be taken as representative of the allocation of inter-industry flows between domestic and imported production. The average element-by-element proportions along the import rows so revealed will initially be taken as applying to all other countries within the same group which have gross flow tables only; the domestic and import matrices will be thus adduced from the import statistics total by sector of origin, as discussed in Section II.

The required GDPs for 1980 will be those used in the FAOs *Commodity Projections 1970-1980*, or through to 1990 if they become available. The 1980 projections are certain to be too high as they did not take into account the inflation and the oil-price-induced recession of the mid-1970s; only 30 percent of the projected increased agricultural demand is higher per capita income as opposed to population induced. Nevertheless, some method for sensitivity testing of the model for differences in assumptions regarding changes in GDPs will have to be devised. Further, we have no tables at all for 1980 (or 1990) so a process of updating pre-1970 inter-industry coefficients to 1970 and of projecting them through to 1980 will have to be devised before the realized 1970 GDPs and projected 1980 GDPs can be fed through the resulting inverses. This may be done in one of three ways or through a combination thereof. These techniques are: the RAS method; a cross-section and/or time series analysis of coefficient change; and the use of the latest, unaltered coefficients.

The RAS method of updating input-output coefficients has been mentioned. It is a technique familiar to that used by research workers in the input-output field. However, it requires a knowledge of intermediate input and value added together with final demand and intermediate output totals for each sector in the matrix. In the majority of cases, we will not be able to obtain the necessary firm data. Thus an alternative approach to updating and projecting matrices must be found unless we are prepared to accept the method for arriving at gross and intermediate row and column totals previously outlined for the base year.

Cross-section and time-series coefficient change research is currently being undertaken at Bradford for the World Employment Programme of the ILO. This has involved examining groups of "standardized" individual country inter-industry flow matrices in both cross-section and time-series. Changes in element coefficients, the so called a_{ij}s, are being regressed against changes in per capita incomes as well as against a variety of other variables. For example, the work may reveal that if we know or can project growth in per capita income from the year of a country's latest input-output table through to our base year of 1970 and our final projection year of 1980, then we may use our lines of regression between individual coefficients and these changes in per capita incomes to project the 1970 and 1980 coefficients of the matrix. But it is already clear that the majority of element coefficient changes will have low coefficients of correlation against changes in per capita incomes, even though we have performed our cross-section regressions on groups of countries of supposedly similar characteristics. So this method seems likely to furnish only a partial solution the problem of updating and projecting our input-output tables. Perhaps it will be best to assume that the coefficients alter in accordance with changes in projected per capita GDPs where the cross-section and/or time series regressions have a high coefficient of correlation, and to leave them constant where they do not.

In any event, the "best practice" country, the USA, constitutes the most important single component of any world model and its coefficients cannot be projected by regression against per capita GDPs in other countries. Fortunately, a number of other element projections are available for the USA.

Time-series and cross-section methods of updating coefficients assume that price relativities do not alter drastically from one period to another and that technology (input-combinations) in more advanced countries represents the shape of things to come in less advanced countries. While such assumptions will not be precisely borne out, they may get us near enough to the truth for our purposes.

The latest coefficients available may nevertheless prove as good an estimate of what the 1970 and 1980 coefficient matrices will look like as any alternative means of projection. Ultimately, we may use unaltered coefficients for our updating and projecting, varying only the relevant final demand vectors.

II. THE INTERNATIONAL TRADE MATRIX

International flows within the model are best determined by means of a trade matrix with all inter-locking individual country matrices expressed in constant 1970 US dollars. A number of such trade matrices already exist in connection with the first three world models listed in Appendix B. No doubt we will be able to draw upon the experience which they provide.

The kind of trade matrix which we have in mind is illustrated in Table 3. We have assumed that the world comprises three countries, A, B and C. In fact, of course, our matrix will include all large- and medium-sized nation states individually, together with aggregations of very small, geographically associated states. Each of the countries is first assumed to have ten sectors in its inter-industry flow matrix as per Table 2, but we represent the matrix by three sectors only in Table 3 for purposes of illustration. These three sector, inter-industry flow matrices for each of the states are strung out along the main diagonal. The off-diagonal matrices comprise the expanded export vectors in Table 2 distributed between countries of destination along the rows, and the expanded import vectors by country of origin down the columns. These last are derived from the import matrices for individual states so that we may know the sector origin of these imports within the exporting country.

Table 3 represents two matrices X and D covering the entire world. X comprises all individual country inter-industry transactions together with associated international trade flows. D constitutes a series of exogenous final demand vectors. X and D may be split, in turn, into sub-matrices x_{ij} and d_{ij}, where

$$X_{nr+i-n,\ ns+j-n} = x_{rsij}$$

and

n = the order of each submatrix; i.e., the number of sectors associated with each country.

The above element represents the supply by sector i of country r to sector j of country s. Similarly, $D_{nr+i-n,s}$ = d-si designates the supply by country r sector i into the final demand of country s. Additionally, we define the value added in country s, sector j as

$$V_{ns+j-n} = v_{sj}$$

Then, for all s and j,

$$v_{sj} + \sum_{ri} x_{rsij} = \sum_{ri} x_{srji} + \sum_{r} d_{srj} \quad ,$$

that is column totals equal row totals within the matrices. Technical coefficient matrices and inverse matrices follow.

A simple numerical example will illustrate the working of the model. Suppose, for example, that country A in Table 3 has a final domestic demand (i.e., exluding exports) of 200, which spills out in the form of 60 in imports direct to final demand, 40 in demand for the output of its own sectors 2 and 3, and 100 in demand for its own sector 1. Of the 100, 40 goes to inputs from the three sectors of its own economy and 40 to imports from countries B and C. The missing 20, to make up 100, would be in the form of value added in sector 1 of country A. Sector 1 in country B supplies the 20 which it exports to sector 1 and to final demand of country A (10 plus 10) by imports of 2 from sector 1 in country A itself and of 4 from sector 2 of country C, while it uses 6 of its own inputs and presumably 8 in its own value added. Thus the domestic final demand in sector 1 of country A spreads throughout the matrix; although for simplicity's sake, we have filled in only two of the 9 columns in Table 3. It is from this process that the realized 1970 international trade flows will have been derived. The conversion of these money flows into element coefficients within the trade matrix will theoretically allow us to compute an inverse which will show the impact on world trade of the projected increases in individual country final demands for 1980 or 1990. The origin and destination of the commodities and services traded are given in fob values within the matrix. This will give us a 1320 times 1320 matrix, if we take into account the 132 countries in the FAO *Agricultural Commodity Projections 1970-1980*, covering 99.6 percent of the world's population. Each of these 132 countries will initially comprise the 10 sectors given in Table 2 rather than three countries with three sectors as given in Table 3. Inverting such a matrix is likely to involve considerable computer time, but presumably it is possible as a matrix of similar size appears to have been inverted for the Harvard US regional input-output model. However, when we expand to the 21 times 21 individual country model discussed in the next section, and outlined in Table 4, computer capacity may become a problem as the time required to do the calculations expands by the cube of the number of elements added. In these circumstances, therefore, we may have to devise some short-cut technique.

We represent the international trade matrix in fob rather than cif prices. Thus, we will have to adjust the cif import figures represented in constant 1970 US dollars in our original individual country input-output matrices to equal the recorded aggregated fob prices in dollars drawn from the OECD origin and destination statistics for 1970. The difference between the fob and the cif aggregates will have to be divided among the various service sectors (10 or 21) of Table 2 or Table 4. Where seas must be crossed, this might be done in accordance with the proportion of the world's shipping tonnage held by different countries in the model. Where trade is overland, we might assume that the cif/fob mark-up goes into the service sector of the exporting country. Both methods involve a number of premises which can never be entirely verified including that of identity of origin for transport and insurance services within the carrying country. But more significant still, we will initially assume that trade patterns do not alter over time and that world prices will not change between 1970 and 1980, or 1990, if the latest commodity projections become available. Clearly, oil has already upset these expectations, and other disruptions are certain to follow. But quixotic assumptions and approximations will survive within the model no matter what we do, and it can not be otherwise. We can only hope that the relative magnitudes which we use will, when presented in modeling form, yield a clearer picture of what is likely to happen, and what might be done in anticipation of such events.

The system may, however, be sensitivity-tested for changes in assumptions and the decision-maker can develop any scenario which he may wish to examine. In addition, we may try to project trade pattern changes by extrapolating the OECD trade statistics' time series. Moreover, the compilers of the FAO *Commodity Projections* are trying to incorporate price projections in their predictions and both the LINK and the Maryland models mentioned in Appendix B adjust prices to changes in international supply and demand. Thus we might be able to incorporate price determination in later versions of our trade model.

Another problem is that the OECD origin and destination trade statistics which we propose to use cover only trade from, to, and between OECD states, and although this must be by far the greater proportion of all international flows, it is by no means all. We will therefore probably have to devise a gravity model on the basis of these known OECD trade flows by means of which we may distribute the origin and destination of the trade values between non-OECD states. Presumably the difference between the sector-by-sector exports and imports of these countries as recorded in the UN *Yearbook of International Trade Statistics* and/or the FAO *International Trade Yearbook* and those given in the OECD *Trade by Commodities* will give the sector-by-sector value of the trade among these non-OECD states. It is this which may be distributed in accordance with some gravity model. The OECD statistics are filed on magnetic tape and we should be able to read them into our model by machine.

III. THE EXPANDED MODEL

We propose first to construct the 10 times 10 individual country and associated international trade matrix as described above. But this contains single agricultural and chemical sectors only, and does not provide us with sufficient detail to construct a world agricultural model. It is therefore our intention to further subdivide both of these sectors once we have shown on the 10 times 10 matrix that such a model works. We also expect to divide clothing and textiles for the reasons outlined in section IV below.

If we compare the proposed aggregation given in Table 4 with our existing 10 times 10 aggregation as represented by Zambia in Table 2, we see that our original agricultural row 1 will be expanded to comprise rows 1 through 7 in Table 4. The chemical sector, row 5, will likewise be disaggregated to comprise rows 8 through 12. Then too, we propose to add land and labor inputs together with wages in rows outside the matrix as per rows 25 through 35 in Table 4. We must therefore outline how we intend to derive these disaggregated rows since most of them do not exist in any of the original input-output tables, although some of them do. We must also discuss the additional column vectors for final demand which are included in Table 4.

We will derive rows 1 to 5 and 7 largely on the basis of the FAO *Commodity Projections*. But these data do not include any information on row 6 of Table 4, forest products. Then too, they will provide us with only demand and domestic supply row totals for projections to 1980 with respect to non-food crops and livestock (rows 1, 3 and 5) and even with them the coverage may not be complete. We must therefore obtain base year domestic supply row totals for rows 2, 4 and 6, 7 from the FAO's *Production Yearbook* and assume that these totals will provide the same proportion of projected demand in 1980 as they did in 1970. The rest will be either imported or exported in accordance with the FAO *Commodity Projections* for 1980 with exporting countries adjusting their supplies to fill the gap. With rows 1, 3 and 5, however, the trade position can be obtained directly from the FAO *Projections*; nevertheless, we anticipate all kinds of difficulties in dealing with the statistics involved here. It may be that we will have to redefine rows 1 to 7 in Table 4 in order to meet the exigencies imposed by the form in which the data are made available. We may also adjust supply and demand through assumed stock build-ups or depletions or through some allegedly price-determining model. Initially, however, we will follow the FAO *Commodity Projections* in holding prices constant.

The same sort of exercise will be carried through with respect to rows 8 to 10 of Table 4. Recorded and projected nitrogen, phosphate and potash row totals can be obtained from the production and planned capacity figures contained in the FAO *Fertilizer Reviews*, and the TVA-USAID data. Fertilizer totals are expressed in metric tons in these sources and they will have to be multiplied by the prices recorded in the FAO *Production Yearbooks*. Clearly, a 1974 or 1975 price deflated by the overall US cost of living index to the base year will be more appropriate than the actual base year price, as nitrogen appears to be the most fuel-intensive of all major manufacturing activities and phosphate rock supply prices have been effectively cartel-determined since 1973. A further complication arises from the fact that recorded fertilizer prices in the FAO *Production Yearbooks* do not always represent true costs and subsidies are widespread. But this will be true of any of the values within our input-output tables where a government intervenes in the market.

The demand totals for rows 1 to 5 and 7 of our expanded matrix in Table 4 will be taken from Table D of the FAO *Commodity Projections 1970-1980* or the equivalent table in the revised projections to 1990 when they are published. These row totals, which are given for the separate types of output, must be aggregated into our seven sector format. They are in thousands of metric tons and will therefore also have to be multiplied by the appropriate price per ton recorded in the FAO's *Production Yearbook for 1970*, or whatever later base date may be appropriate for any revised projections through to 1990. This will give us a constant dollar demand total for rows 1 to 5 and 7 from, say, 1970 to 1980.

Pesticides and fungicides, row 11, can be obtained in row totals, in quintals, from the FAO *Production Yearbook for 1970*, or whatever base year we eventually choose, and extended through to 1980 or 1990 at constant US dollar prices on the basis of such technical coefficients as may be projected for their use. Unfortunately, we have not yet identified a source of price information in this respect and this problem remains to be overcome. Row 12, other chemicals, should be the residual of row 5 in the Table 2-type 1970 matrix (updated from 1969 in the case of Zambia) minus rows 8 to 11 in the Table 4 matrix for each and every country covered in the model. The remaining rows will be as for Table 2 in the base year, except that the textile row totals will be divided between clothing and other textiles on the basis of the data contained in the UN *Yearbook of National Accounts*. The method of projecting these rows to 1980 or 1990 was described in section I. But dividing up row totals along the lines outlined will not solve the attendant problem of allocating these totals between the elements along the rows not included in Table 2 and it is to this question that we now turn.

Grains, other arable, non-food and permanent crops, livestock, forest products and fish (rows 1 to 7 in Table 4) will be particularly difficult to allocate between matrix elements. Some data exist on inter-industry flows for these different agricultural goods in the FAO *Commodity Projections*, in the FAO *Production Yearbooks* and in some of the original input-output tables, but they are not as detailed as we would wish. There are, however, a substantial number of "food balance sheets" for several countries, and these may, perhaps, be obtained from the Commodity Division of the FAO, or from the individual countries concerned. These data may show the destination of food products in terms of processing, final demand or whatever. Where they exist they may be considered as representative of proportional row distributions of output in all countries of a similar type. Then too, we understand that Dr. Shaw of the Economics and Marketing Division of the Tropical Products Institute in London is exclusively concerned with the post-harvest treatment of commodities; he is seeking the breakdown of destination of outputs in a manner which may help us to derive rows 1 to 7 of Table 4.

Regardless of the source, we would expect our agricultural row totals to display a systematic tendency to move between the different elements making up their respective rows as per capita incomes increase; as bread is baked outside the household and the like. We will have to try to decide what these movements might be in order to represent row coefficients in 1970 and to project them to 1980 or 1990. Whatever the result, individual row elements in the base year, 1970, for rows 1 to 7 in Table 4 should be reconciled with the actual recorded and/or updated elements for the single agriculture row (row 1 in Table 2) where we actually have input-output tables;

appropriate adjustments may have to be made to individual commodity row elements. In other words, element 1/1 in Table 2 will become a 7 times 7 sub-matrix in Table 4 and these matrices may have to be adjusted in the light of Table 2's element totals. The same applies to the relationship between row 5 in Table 2 and rows 8 to 12 in Table 4, as discussed below.

Fertilizers, pesticides and fungicides and other chemicals (rows 8 to 12 in Table 4) will have their row totals determined from a variety of sources. The FAO's *Annual Fertilizer Reviews*, plus information obtainable under the TVA-USAID contract, together with the prices given in the FAO *Production Yearbooks* will furnish the totals for rows 8 to 11 in Table 4. Other chemicals will comprise the totals for row 5 in Table 2 minus rows 8 to 11 in Table 4.

It will not be clear from these sources how fertilizer inputs are distributed between columns 1 to 6 as well, as into final demand for gardens and golf courses, and the same applies to pesticides and fungicides. Technical advice will therefore have to be sought on the subject. Dr. J.A. Clark and Mr. Gordon MacKerron of the Science Policy Research Unit at the University of Sussex, Dr. David Norse at the UK Department of the Environment, and Professor George Allen at the University of Aberdeen are all working on these or similar problems. Grains are clearly the major consumers of fertilizers in most countries. We understand that the Mesarovic-Pestel model cited in Appendix B simply assumes that grains take 75 percent of each and every country's fertilizer consumption; throughout Latin America it is not nearly so much and the pattern varies widely from country to country. Most fertilizer consumption in Sri Lanka, for example, is for the purpose of growing tea.

Other inter-industry flows (rows 12 to 21) will be taken directly from the individual country 10 times 10 tables as per Table 2. They correspond to all but rows 1 and 5 therein, except that textiles will be split into clothing and other textiles. This last split in row total form can generally be obtained from the UN *Yearbook of National Accounts Statistics* for the base year, but dividing the elements in columns 1 and 5 in Table 2 between columns 1 to 12 in rows 13 to 21 will be more difficult. Initially the original element totals in columns 1 and 5 of Table 2 will probably have to be divided in proportion to the new totals for rows 1 to 12 in Table 4.

Value added (row 23), as has been shown, can be derived for the base year, 1970, from the UN *Yearbooks of National Accounts Statistics* although the elements along the rows in Table 4 do not correspond exactly with the value added in each country recorded in these *Accounts*, and approximate distributions will have to be arrived at. Then too, value added raises a further problem. It is unlikely that 1970 GDPs processed through updated inverses will yield the value added in each sector recorded in the UN *Yearbook of National Accounts Statistics*, and the problem of reconciling the two outlined in Section I will have to be either ignored or faced. It may not be necessary to resolve them if the 1970 GDP spills out into value added in sector proportions close to those revealed by the *Yearbook*.

Land under grains, other arable, non-food and permanent crops, forest and irrigation, (rows 25 to 31 in Table 4) will be derived from a variety of sources. The FAO *Commodity Projections* (1970 to 1980) can supply us with the data for columns 1, 3 and 5. This source also anticipates the yields per hectare in 1980 for each of these sectors. It is with respect to such projected yields that we will take expert advice on the product-by-product pattern of input change outlined above. Land under crops in columns 2, 4 and 6 will have to be derived from the FAO *Production Yearbook* for the 1970 base year. Land area used for these purposes is not predicted in the FAO *Commodity Projections*, but presumably it can be obtained by taking estimated output in 1980 and dividing it by some estimate of yields on a crop by crop basis. Other projections may be obtained from E.O. Heady, *World Food Production and Demand to 1985 and to 2000*, (Iowa State University Press) and the FAO *Indicative World Food Plan*. Estimates of the absolute limits of area (rows 32 and 33) and possible production per hectare in different parts of the world are contained in P. Buringh, H.D.J. Van Heemst and G.J. Staring *Computations of Absolute Maximum Food Production in the World* (Wageningen, Agricultural University, 1975); this study was initiated by the Club of Rome.

Irrigated lands (row 31) do raise some difficulties for us, since the FAO *Production Yearbooks* do not allocate the total area under irrigation between crops in a country. Moreover, these areas are part of the totals involved in inter-industry flows mentioned above and comprise areas commanded by existing infrastructure rather than land actually under irrigation. We may simply have to relate total irrigated areas, which we do know from the FAO *Production Yearbook*, to total 1970 and projected 1980 or 1990 agricultural output on the basis of some constant ratio of output to irrigated area, up to the limits given in Buringh et al. This is unsatisfactory, and we hope to improve on this method as the research proceeds. Sensitivity testing here, as elsewhere, may provide some solutions to our problems.

Employment and wages are given in rows 34 and 35. Agricultural employment can be obtained from the data in the FAO *Production Yearbook*. This total will be subdivided on technical advice relating to value added between the individual columns 1 to 7. Alternatively, it may be possible to take average labor productivity from data against value added per agricultural sector. Both value added data per crop and overall agricultural wages can be obtained from the FAO *Production Yearbook*, and information on productivity per worker is available from the ILO *Yearbook of Labour Statistics*. Often real wages on plantations, i.e. some proportion of permanent crops under 2 above, are three or four times as high as earnings in subsistence grain production and this complicates the issue. Nevertheless, we will try to introduce this wage element into the table not only in order to help us obtain ratios of employment to value added, but also because we may want to know how different final demand scenarios will affect income distribution when they are processed through the inverse matrices. But more of this in Section IV.

Other employment and wage figures for the remaining sectors of the matrix will be derived from the ILO *Statistical Yearbook*, OECD employment data, the Commission of the EEC, the United Nations Statistical Office, the Economic and Social Commission for Asia and the Pacific (ESCAP), in particular the *Sectoral Output and Employment Projections for the Second Development Decade*, Development Programme Series No. 8, Bangkok 1970. It may also be that 1970 ratios of sector output to sector employment can be projected to, say, 1980 on the basis of work currently going on at the ILO under the World Employment Programme. As has been said, we are already helping with this Programme, and, if they are able to provide us with such data, then many of the problems connected with employment estimates will be solved.

Final demand (column vectors 23 to 29) must be added to the data which we would normally have with our existing 10 times 10 inter-industry flow matrices. Domestic final demand (columns 23 and 25) will be arrived at in the manner already discussed. Exports (column 24) will become a function of the operation of the trade matrix. Any projected additional irrigation and land clearing or improvement costs, both capital and current, will have to be added to final demand as column vectors (27 to 29). In other words, there will have been some irrigation development and current outlays contained in the original matrix for our base year of 1970, but if the pace of irrigation development is quickened in 1980, perhaps under higher cost conditions, then we will have to incorporate an increment to annual capital expenditure and current outlays for irrigation in column 27 of our 1980 matrix. Base year agricultural investment data can be obtained from the UN *Yearbook of National Accounts Statistics*. Different incremental land development costs by region are given in Buringh et al, and these may also help us here. Then too, Dr. David Norse of the UK Department of the Environment is attempting to calculate what such costs might be, and perhaps we will be able to draw on his advice in this respect. He is working on the basis of feasibility study estimates obtained from the library of the UK Ministry of Overseas Development. But columns 27, 28 and 29 do involve difficult and esoteric calculations and may have to be dropped from the initial model as separate items.

IV. USES OF THE MODEL

The question naturally arises as to why one should go to all the trouble of building a world agricultural model in the detail described in the foregoing three sections. Any answer must really lie in identifying some virtue in using standard format individual country input-output matrices with the associated trade matrix. After all, less detailed models with respect to economic structure are already under construction and they should help to answer many of the questions which individual country planners and international aid officials or investors may want to ask.

The distinguishing characteristic of input-output analysis is that it shows how changes in production in one sector are linked to changes in production in another; we may give examples of the uses to which this can be put. We may, for instance, predict that country A's grain production must increase by Y dollars at constant prices if it is to play a part in feeding an expanding and possibly individually-richer world population on a given land area. This should then allow us to determine from our input-output matrix for country A the necessary expansion in fertilizer consumption. Initially this may involve country A in more imports of nitrogen, potash, phosphates, oil, etc., and country B in expanded output to supply these imports; the trade matrix will indicate the amounts involved. The inter-industry flow matrix for 1980 or 1990 for country A may then reveal that such a volume of input of nitrogen or whatever into agriculture will allow for the establishment of a domestic manufacturing plant with the appropriate economies of scale. Whereupon the input-output table will show how the import pattern shifts from, say, nitrogen to fuel with the corresponding balance of payments effect. It will also show how utilization of plant in existing nitrogen exporting countries will be altered and what adjustments may be needed therein.

It would be possible, assuming that we can designate a minimum and/or an optimum nitrogen plant capacity, to print out those countries which may begin now to plan for domestic nitrogen production designed to come on stream in 1980, over and above that already identified in the FAO's *Annual Fertilizer Reviews*. Similar changes in economic structure may be identified throughout individual economies as a consequence of anticipated increases in grain production. Such changes may involve both direct inputs such as nitrogen, and indirect inputs into nitrogen itself in the form of fuels. The international trade ramifications may also become clear. An international aid agency or bank, for example, may thus be alerted to the countries in which the establishment of nitrogen manufacturing capacity may be worthwhile from a market point of view, or where planned investment in further nitrogen capacity might be reconsidered in the light of falling possibilities for exports to those countries which may now anticipate their own production. It then becomes reasonable to take up these issues with each country's planning authorities to see if they can identify any marked inaccuracies in the crude calculations of our global model. A variety of such checks may be carried out in connection with whatever periodic economic survey reports the international agency in question may carry out on country A. If country A's officials agree with the model's diagnosis that the required domestic nitrogen consumption threshold will be reached by 1980, then the international lending agency may suggest to an appropriate organization, such as the United Nations Development Programme (UNDP) or the UK, ODM, that a feasibility study be undertaken on nitrogen production facilities. At this stage, any important inaccuracies in the crude world model from a market point of view will be revealed if they exist, or the plant may be ruled out on the basis of cost projections which make it uneconomic. But the point is that the initial world model acts as a project identification technique of a more or less systematic kind and it may do this for a wide variety of enterprises on the basis of different scenarios regarding country growth rates, trade-offs with respect to extensive and intensive land development, and so on. It may be, of course, that the ensuing detailed individual project appraisals will show that individual components of the world model are not working particularly well. If this is the case, then they will have to be revised. The kind of issues which a systematic examination of these project appraisals would throw up could lead to alternative parameters in the model so that the examination operates as a satisfactory identifier of projects.

If we assume that the model can be made to work in a satisfactory way, then we can develop a wide variety of scenarios. For example if wage and employment data are incorporated in the model along the lines suggested, then the employment-income-distribution consequences of various types of global aid and loan strategies may be worked out. In this respect, the International Wool Secretariat (IWS) has been asked by the Conference Division of the ILO to make proposals for conducting research on "the scope of employment opportunities in the clothing industry with particular emphasis on developing countries", to be financed by the UNDP. We at Bradford have, in turn, been asked by IWS to help with this study. If finance can be found for constructing the world agricultural model proposed here, then the input-output impact of transferring more of the world's clothing industry to poor countries could be worked out in terms of the sector breakdown of this model. Clothing manufacture is a particularly labor-intensive activity and the income-effect of its expansion will substantially influence the demand for food as well as for cotton and wool. The projections required under this ILO-IWS contract could be developed within our input-output framework and the consequent impact of the enhanced purchasing power for agricultural production worked through the model. This kind of analysis may be particularly useful since it is often agreed that the ability to grow food is not a major constraint; rather it is the inability of the underemployed to buy food that constitutes the real problem.

The list of other uses for our system of inter-locking matrices is potentially very large. The model should reveal the outlines of the overall changes which must take place in the economic structure of individual economies and of world trade, if all are to be fed and clothed five, ten or fifteen years hence. These structural changes may vary according to the strategies developed upon the model; i.e., increased poor-country industrial exporting in exchange for increased food imports from the developed countries, increased industrial and food trade among the poor countries themselves, increased agricultural self-sufficiency on the part of the individual countries within the model, and so on. The expectation is that, despite the inevitable inaccuracies of the existing data and despite any failure of projection to accord exactly with realization, the model will provide a better basis for planning world food production than would otherwise be available. Imperfect it will cetainly be, but will it be more so than any alternative construction?

Appendix A: Standard Format for Bradford Tables.

Table A-1. Flows: fractions of total output, Zambia, 1969.

		1	2	3	4	5	6	7	8	9	10
Agriculture	1	0.00056	0.00112	0.00976	0.00061	0.00061	0.00002	0.00066	0.00012	0.00000	0.00029
Mining	2	0.00010	0.01676	0.00007	0.00000	0.00012	0.00069	0.00022	0.00077	0.00101	0.00004
Foodstuffs	3	0.00064	0.00026	0.00625	0.00000	0.00028	0.00000	0.00025	0.00000	0.00000	0.00540
Textiles	4	0.00061	0.00007	0.00046	0.00459	0.00002	0.00001	0.00015	0.00002	0.00000	0.00107
Chemicals	5	0.00427	0.00739	0.00331	0.00033	0.00675	0.00078	0.00228	0.00242	0.00021	0.01021
Metal Mnfg.	6	0.00102	0.00779	0.00109	0.00015	0.00025	0.00612	0.00313	0.01824	0.00105	0.00727
Unspecified Mnfg.	7	0.00115	0.01348	0.00108	0.00045	0.00049	0.00114	0.00605	0.00345	0.00000	0.01410
Construction	8	0.00042	0.01350	0.00629	0.00027	0.00031	0.00048	0.00550	0.00964	0.00014	0.00829
Energy	9	0.00062	0.00865	0.00050	0.00006	0.00012	0.00022	0.00227	0.00029	0.00971	0.00504
Services	10	0.00140	0.03743	0.00673	0.00110	0.00243	0.00326	0.01456	0.00847	0.00028	0.05705
Intermed. Input		0.01078	0.10646	0.03553	0.00756	0.01139	0.01271	0.03506	0.04141	0.01239	0.10877
Value Added		0.03559	0.31709	0.02410	0.00480	0.00811	0.00912	0.00229	0.04144	0.00729	0.16812
Total Input		0.04638	0.42354	0.05962	0.01236	0.01950	0.02183	0.03735	0.08285	0.01968	0.27689
* * * * * * *	*	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *
Import Now		0.00478	0.01439	0.00869	0.00485	0.00592	0.00312	0.01056	0.01910	0.00990	0.01790
* * * * * * *	*	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *
Intermed. Output		0.01375	0.01977	0.01308	0.00698	0.03794	0.04412	0.04140	0.04485	0.02748	0.13270
Final Demand		0.04020	0.40667	0.06070	0.02469	0.01547	0.07044	0.00874	0.03985	0.00189	0.16850
Domestic		0.03752	-0.01545	0.06013	0.02440	0.01527	0.06441	0.00819	0.03985	0.00189	0.13687
Exports		0.00268	0.42212	0.00057	0.00028	0.00019	0.00602	0.00055	0.00000	0.00000	0.01163
Gross Output		0.05395	0.42644	0.07378	0.03167	0.05341	0.11455	0.05014	0.08470	0.02937	0.30121
Import Column		0.00758	0.00289	0.01415	0.01931	0.03391	0.09272	0.01279	0.00184	0.00969	0.02432
Total Output		0.04638	0.42354	0.05962	0.01236	0.01950	0.02183	0.03733	0.08285	0.01968	0.27689
* * * * * * *	*	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *	* * *

Table A-2. Technical coefficients, Zambia, 1969.

		1	2	3	4	5	6	7	8	9	10
Agriculture	1	0.01210	0.00265	0.16306	0.04954	0.03141	0.00071	0.01764	0.00143	0.00000	0.00106
Mining	2	0.00211	0.03956	0.00112	0.00000	0.00607	0.03159	0.00579	0.00932	0.05126	0.00013
Foodstuffs	3	0.01376	0.00061	0.10479	0.00000	0.01452	0.00000	0.00661	0.00000	0.00000	0.01952
Textiles	4	0.01310	0.00017	0.00768	0.37136	0.00079	0.00024	0.00413	0.00019	0.00000	0.00385
Chemicals	5	0.09200	0.01744	0.05550	0.02664	0.34636	0.03583	0.06104	0.02919	0.01046	0.03688
Metal Mnfg.	6	0.02197	0.01840	0.01850	0.01249	0.01267	0.28053	0,08378	0.19397	0.03535	0.02626
Unspecified Mnfg.	7	0.02486	0.03184	0.01813	0.03664	0.02534	0.05233	0.16191	0.04162	0.00000	0.05091
Construction	8	0.00910	0.03188	0.10548	0.02165	0.01610	0.02192	0.14717	0.11640	0.00706	0.02994
Energy	9	0.01332	0.02043	0.00837	0.00458	0.00634	0.00990	0.06077	0.00354	0.49320	0.01822
Services	10	0.03019	0.08838	0.11282	0.08868	0.12460	0.14922	0.38997	0.10218	0.01438	0.20604
Intermed. Input		0.23249	0.25135	0.59586	0.61157	0.58421	0.58227	0.93882	0.49984	0.62971	0.39282
Value Added		0.76751	0.74865	0.40414	0.38843	0.41579	0.41773	0.06118	0.50016	0.37029	0.60718
Total Input		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
* * * * * * * * * * * *											
Import Now		0.10299	0.03399	0.14579	0.39259	0.30385	0.14286	0.27739	0.23051	0.50288	0.06466
* * * * * * * * * * * *											
Intermed. Output		0.29653	0.04667	0.21934	0.56495	1.94615	2.02074	1.10845	0.54128	1.39618	0.47927
Final Demand		0.86683	0.96016	1.01804	1.99709	0.79329	3.22631	0.23412	0.48096	0.09623	0.60856
Domestic		0.80912	-0.03648	1.00855	1.97419	0.78353	2.95050	0.21937	0.48096	0.09623	0.56655
Exports		0.05771	0.99663	0.00950	0.02290	0.00977	0.27581	0.01474	0.00000	0.00000	0.04201
Gross Output		1.16336	1.00683	1.23738	2.56203	2.73944	5.24705	1.34257	1.02224	1.49242	1.08782
Import Column		0.16336	0.00683	0.23738	1.56203	1.73944	4.24705	0.34257	0.02224	0.49242	0.08782
Total Output		1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
* * * * * * * * * * * *											

Table A-3. Leontief inverse, Zambia, 1969.

		1	2	3	4	5	6	7	8	9	10
Agriculture	1	1.02316	0.00691	0.19498	0.08747	0.05788	0.00974	0.03630	0.00897	0.00339	0.01234
Mining	2	0.00794	1.04760	0.01075	0.00708	0.01595	0.05316	0.03074	0.02526	0.11248	0.00855
Foodstuffs	3	0.02113	0.00591	1.12906	0.00991	0.03390	0.01111	0.02976	0.00881	0.00350	0.03209
Textiles	4	0.02280	0.00206	0.02025	1.59522	0.00610	0.00414	0.01459	0.00334	0.09109	0.00977
Chemicals	5	0.16280	0.05175	0.15980	0.11151	1.57397	0.11991	0.20022	0.10060	0.05457	0.09965
Metal Mnfg.	6	0.05627	0.06129	0.10403	0.07737	0.07107	1.44602	0.26682	0.34744	0.16731	0.08823
Unspecified Mnfg.	7	0.04874	0.05909	0.06743	0.10132	0.07755	0.12291	1.27808	0.10197	0.02467	0.09626
Construction	8	0.03044	0.05733	0.16396	0.07193	0.05982	0.07503	0.25571	1.17142	0.03327	0.07103
Energy	9	0.04091	0.05814	0.04739	0.04262	0.04493	0.06095	0.19276	0.04026	1.98880	0.06505
Services	10	0.11006	0.17504	0.27102	0.27553	0.31645	0.37020	0.75638	0.28755	0.10570	1.35639

* *

Appendix B: Some Existing World Models

1. Professor L.R. Klein, PROJECT LINK, Economic Research Unit, University of Pennsylvania, Philadelphia. The project consists of: 13 individual country models; regional models for four developing areas; some reduced form equations for 12 other developing countries; trade models for the CMEA group of socialist countries, and an international trade matrix connecting these components. It is supported by the United Nations.

2. The International Monetary Fund Trade Model, R. Rhomberg, Washington, D.C. It comprises a 25-country, four commodity model.

3. The Dynamic World Regional Input/Output Model, Professor Douglas Nyhus, University of Maryland, College Park, Maryland, U.S.A. It includes 10 developed countries plus a very simple rest-of-the-world model.

4. The World Food Model, Professor H. Linnemann, Economic and Social Institute, Free University of Amsterdam. According to the Institute, "The model describes the development of the entire agricultural sector in each country, or group of countries. The total number of geographical units is 106. Development of the non-agricultural sectors is exogenous to the model and so is population growth."

5. The Bariloche World Model, A. Herrara, Fundacion Bariloche, Argentina.

6. The Mesarovic-Pestel World Model, University of Hannover, Federal Republic of Germany, and the Limits to Growth Model, Donella Meadows, et al., Dartmouth College, New Hampshire. These are the well known Club of Rome systems-dynamics models.

7. The World Employment Model, Dr. Gerry Rodgers, International Labour Office, World Employment Programme, Geneva, Switzerland. This model is based upon input-output analysis with the USA representing the structure of developed economices and Mexico and/or the Philippines representing the structure of underdeveloped economies.

8. The World Environment Model, W. Leontief, Department of Economics, Harvard University, Cambridge, Massachusetts. This model uses input-ouput analysis on a world regional basis to deal with problems of pollution control and exhaustion of natural resources.

9. World Input-Ouput Model, Professor Y. Kaya, University of Tokyo, Japan.

10. The UK Department of the Environment World Model, Dr. P. Roberts, Systems Analysis Unit, Department of the Environment, Marsham St., London SW1, UK. This is another world regional input-output model with detailed agricultural treatment under Dr. David Norse.

11. The Science Policy Research Unit Model, Dr. J.A. Clark and Mr. Gordon MacKerron, SPRU, University of Sussex, Brighton, UK. This model is in the first stages of formulation.

Note: None of the above input-output models comprises anything approaching the number of individual country inter-industry flow matrices contained in the Bradford system.

Discussion

Bruckmann raised the general question of how valid input-output techniques are when applied to agriculture. A Leontief production function is, by definition, limitational, i.e. a doubling of all inputs leads to exactly double the output. This production function, at least in the short run, is applicable for many manufacturing processes, but not in agriculture. In agriculture there are: a) definite diseconomies of scale (diminishing returns); and b) absolute limiting factors, such as availability of land and water. At the least, these factors may play a sufficiently large role to question the validity of this enormous task.

Bottomley replied that their work includes updating input-output coefficients, by means of regression analysis, which unfortunately has shown only low correlation coefficients.

Richardson advised that in such a large-scale venture there is a certain danger of becoming so deeply intrenched in data that one might loose control of what is happening unless one controls by using meta-indicators.

Kaya asked where input-output data for China were obtained; Bottomley replied that they came from a Japanese source. Taylor stressed the fact that he knew these data to be unreliable. Bottomley pointed out that in his venture there was a need to use whatever data were available.

Kamrany inquired about the updating procedure envisaged. Taylor replied that for the thirty most important countries (which represented 77% of trade and 86% of GNP) the official national accounting data are used in a modified draft method; for the less important countries the coefficients might be held constant.

Cole stressed the role of time lags in any input-output table: coefficients normally are several years old, and if used for forecasting purposes might be misleading. Rademaker joined Cole in questioning the usefulness of this approach for forecasting purposes; the main field of application as he sees it could be to investigate the outcome of the alternative policies if they had been taken up at some time in the past.

Bottomley added that, besides the overall project, certain parts have been taken up, for example, an EEC model in the form of a 6 x 6 matrix, to be extended to a 21 x 21 or a 35 x 35 matrix.

A Two-Level Multi-Nation Model for Development Planning

-Towards a Balanced Development Between Agriculture and Industry-

Y. Kaya, A. Onishi, and H. Ishitani

I. INTRODUCTION: GLOBAL SOCIETY AT THE TURNING POINT

The World Economy In Transition

The global society in which we now live is in the most far-reaching period of transformation in this century. The industrial society which first became dominant within Western European civilization in the 18th century has during the latter half of the 20th century and in the more economically advanced regions already reached its highest stages of development. Japan, which was later than Western Europe in thrusting itself into this industrial society, has, in little more than the century which has elapsed since the Meiji Restoration, caught up with the levels of development achieved in the industrial society of Europe.

The wave of the industrial revolution, which had its start in England at the end of the 17th century, was rapidly propagated to the European continent and to North America, and in the course of time to Japan in East Asia. The expansion of industrial society, which often took place according to principles of exploitation and "survival of the fittest" type competition, had effects that reached not only throughout the confines of the countries where industrial society first saw growth, but also penetrated into far distant lands as well, in such a way that this expansion acted to incorporate the economies of all countries into an international framework that was both "organic" and marked by contradictory and unmatching interest.

International relations in modern times continued to be governed, as before, by the principles of domination and subservience which had characterized the Middle Ages, and those powers which were large in an economic and military sense dominated the smaller and weaker countries. This sort of principle, which once enjoyed wide acceptance almost as if it had been considered the only principle which could or ought to govern society was very influential in the formation of the modern world economic order. In all places where the influence of this principle was felt, the international economic order which developed centered on the industrially advanced states. Natural resources and wealth, and even human resources came to be concentrated in the industrially advanced countries, while the less developed countries, typically placed in relationships of subservience and exploitation, were kept in a pre-industrial state of society. As Swedish economist and sociologist Gunnar Myrdal has pointed out,(1) mechanisms were built into international society whereby the more advanced countries could become richer and richer and most or many of the less advanced countries could become poorer and poorer--as happened.

The energy which transformed Europe's feudal society into a modern society came in large part from the desire for the recovery of rights on the part of individual people who had been part of the repressed masses of the pre-modern age. Similarly, there came, after the Second World War, an explosion of demand for the recovery of rights on the part of individual countries in those regions whose less-developed state had continued since the Middle Ages and which were being repressed by modern international society. While the industrially advanced countries have been getting richer and richer, demands for vast change in a world economic order which is considered to function at the expense of handicapping the progress of the less-developed countries are gradually coming to the fore among the large number of new nations that have become free from former colonial status, and these nations' political voice can no longer be ignored by the industrially advanced nations.

The establishment of the International Monetary Fund and of the General Agreement on Tariffs and Trade which supported the world economic order after the Second World War were measures aimed mainly at the expansion of trade among the industrially advanced countries and at a stabilization of exchange rates. In the building of these structures an especially great role was played by the United States.

The dollar standard and the principle of free trade were adopted at a time when the United States economy was the core of the world economy, much like the sun within our solar system. One may discern here a system structure in which a group of industrially advanced countries were planets, and a large number of economically less developed countries assumed the position of satellites. The international dynamism which underlay the subsequent development of this world economic system was in the fluid balance between the forces of attraction in the direction of the large and powerful United States economy and forces opposing this attraction.

However, the expansion of the international influence of those regions with centrally planned economies, the changes in the economic power relations with the United States brought about by the increased prominence of the European Community and Japan, together with the expanded influence of the developing countries, have been major factors in the gradual erosion of the post-war world economic order that was centered around the United States. It is also noteworthy that the rapid advance of inflation which accompanied the enormous growth in United States expenditures on the Viet Nam war helped bring on the collapse of the IMF system based on the dollar standard and gave rise to the current use of flexible exchange rates.

The inflationary any pressures which issued largely from the United States and spread throughout most of the other industrially advanced countries caused an undue widening between price increases for energy and other resources exported by the developing countries and price increases of manufactured products exported by the industrially advanced countries. One ought to be able to recognize that the raising by Middle Eastern countries of oil export prices was sudden and forceful correction of this unbalance by which resource prices had for long been unjustly depressed in relation to the prices set by industrially advanced countries for export of their manufactured goods. This all signifies the beginning of a more vigorous process of rights recovery by a large number of developing countries, which have heretofore been handicapped by restrictions imposed by the industrially advanced countries. The declaration of enforcement of perpetual sovereignty over natural resources which was approved by majority vote in the United Nations General Assembly in 1975 [(2)] is a knell warning of the end of an age in which industrially advanced countries could, in their efforts to raise the levels of welfare of their own people, unjustly depress prices paid for natural resources from the developing countries. It is also a thundering at dawn, announcing the opening of the new "era of globalization".

The Opening Of The Era Of Globalization

There are a number of topics such as resources and energy, food, population, economic growth, inflation, monetary systems, environment and personal values any of which, if examined, would show that our society is fast advancing toward an "era of globalization"--this is to say, an age in which workable solutions, as seen from a global viewpoint, are being made urgently necessary.

Until recently economists were predicting a situation whereby production of petroleum, one of the earth's limited resources, would soon be subjected to stringent controls, or predicting the present situation whereby many countries, largely due to the four-fold increase in the price of petroleum within just two years, have been beset with the steep advance of inflation, and stagnation of economist growth.

The report entitled "The Limits to Growth", prepared by the Meadows group and submitted to the Club of Rome in 1972, called attention to the global restrictions on growth and, warned of the global limitations imposed by resources, food, environmental pollution, etc. The report recommended the eventual attainment of what was termed "zero growth." But, when speaking of such matters as limitations of natural resources or self-sufficiency in food, we must recognize that within the present-day global society in which there are great differences among various countries in the way this issue is veiwed. To say that resources and food are insufficient is not to say that this situation holds equally true in all countries. The scenarios in the "have countries" are quite different from those of the "have-not countries".

In the report entitled "Mankind at the Turning Point" prepared by the Mesarovic and Pestel group and presented at the Club of Rome meeting held in West Berin in October, 1974, the world was divided into 10 regions and various "scenarios" were depicted for economic patterns subject to the limitations in petroleum and food resources.

Concerning shortages of foodstuff supply, for example, the report predicts that whereas this problem will become more serious in South Asia, a region of excessive population pressure, such a situation is not expected to occur in the

North American region. This is an example of the "regional differences" we have spoken of. It is also predicted that, in relation to dwindling petroleum resource, global society would face a great crisis of opposition if oil producing and oil consuming countries should become more severe. The report calls for a new age in which all countries put an end to self-centered patterns of growth and effect a transition to a pattern of what they call "organic growth" in which harmony in economic growth would be worked out on a global level.

The orientation in this report was not "zero growth" in the industrially advanced countries, but rather a seeking after "appropriate levels of growth." The experience of the "oil shock," which brought in its wake one type of zero (or near-zero) economic growth under conditions of restricted supply of natural resources, had, in the interval between the two above-mentioned reports, served as an opportunity for the meaning of "zero economic growth" to be reconsidered from an international standpoint.

One fundamental problem is that zero growth in the industrially advanced countries tends to hinder economic development in the developing countries, thus it still more difficult to solve the "North-South problem". Another fundamental consideration is that the present-day free market system could not be maintained under zero growth conditions. If the advanced industrial countries were forced to the level of zero growth under conditions of restricted petroleum resource, this could well to a crisis threatening collapse of the capitalist market system. In this latter sense, what one might call the "limits to zero growth" are in large part to be found in the capitalist market system as such.

On the other hand, seen from the perspective of the history of civilization, it is a present reality that human society has entered an age of tightening global limitations on natural resources. That there should begin to be a quickening of movements toward a new international economic order, and also toward a transition to value systems which are appropriate to this new age, may be called a natural course of development. If free rein should continue to be given the so-called "logic of force" and to the closely related sort of behavior by which individual nations act as they please, human society will be at the brink of a great crisis.

And it is in this connection that it is necessary to reconsider the meaning of the limitations of resources with which our global society must cope. Before there arises an absolute insufficiency of resources on a global scale, there is, as is already the case, the situation of relative resource insufficiencies, imposed by the deficiencies in the present-day international economic system. In spite of the fact that the earth's natural resources are, fundamentally, the common property of all humans, their use has been largely under the control of large cooperations based in the major industrial powers. As pointed out earlier, the United Nations declaration on rights of permanent national sovereignty over natural resources is a historic milestone in the developing countries' opposition to domination by major industrially advance countries or by giant multinational cooperations.

But at the same time, this declaration tends to make even more pronounced the often polarized divisions between those countries within our global society which happen to possess a relative abundance of natural resources and those countries which do not. By becoming thus involved in the relationships between resource-possessing and non-resource-possessing countries, this declaration has further complicated

North-South economic relations. As long as present-day global society continues to be divided along lines of each country's "national sovereignty," with the egoisms of various countries continuing to stand in opposition to one another, the reality of limited resources will crop up in the form of other sharp and unpleasant aspects of the problem. Most especially, should countries with large amounts of resources use their mineral or food resources as "weapons" in their relations with other countries, seeking thereby to uphold their own positions in the world economy, this would cast an evil and unfathomable shadow over the future economic course of the world.

International Economic Policies Under Pressure To Change

At the United Nations Food Conference of 1974, there was general agreement on the need for a worldwide information system with respect to food. In the global society in which we live, it is not only with respect to food, however, that interdependent systems structures exist among all countries. For example, there are interdependent relationships among countries with respect to economic growth, trade, resources and energy, population and environment, and moreover there are globally interdependent relationships among more specifically defined sub-sectors of each of these. Furthermore, the total system of relationships is characterized by the fact that it changes dynamically over time. If we think for a moment of the objectives of Japan's plans for economic growth, we see that there is not now a single one of them that our country is able to achieve wholly on its own. The Japanese economy, which is hypersensitive to limitations of energy resources, cannot achieve proposed economic growth rates in disregard of the limitations imposed by the balance between supply and demand of primary energy resources, especially petroleum.

The development of technology for the exploitation of sources of energy other than petroleum is advancing, but it is generally considered that it will be only after the beginning of the 21st century that these substitute energy sources will replace oil on a large scale, and until that time Japan's energy supplies will have to rely on overseas sources of petroleum.

Under such circumstances, we must recognize that Japan's economy will remain highly dependent on petroleum through the end of this century, even though we may at the same time be groping in new directions toward a "post-petroleum age" to be achieved through changes in industrial structure and technology. In other words, the tempo of Japan's economic growth is affected by the degree that it is possible to import petroleum from abroad. If the acutal tempo of economic growth should be greater than this "potential growth rate," then the balance between energy supply and demand will be upset and this situation will invite advancing inflation and a worsening of the international balance of payments. Japan's excess capacity to supply exports as well as its capacity to expand imports is likewise determined by the state of this "potential growth capacity."

This situation applies not only to the Japanese economy, but also in greater or lesser measure to the economies of all countries which are placed under conditions of limited energy resources. Consequently, under conditions of limited energy and other natural resources, the curtain is beginning to be raised on an era of global management of various countries' economic growth and trade. First, use should be made of a "world economic system model" as part of the start being made in the search for new orientations through which to examine the degree to which the economic policies of the industrially advanced countries, singly and as a whole, achieve international harmony in their relations with the oil producing and other developing countries.

The realization of the fact of the limitations of global resources, which has first become prominent with regard to food and petroleum, cannot help but have as one of its effects that of making each country think anew about how to use resources most efficiently. Along with efforts toward reduced exploitation of resources, there will probably be, in response to the demands of the new age, greater encouragement given the development of "closed systems" for resource recycling. Also, for purposes of attaining a new dimension of harmony between humans and nature two indispensable elements will be the unimpaired availability and utilization of science and technology for the benefit of all people and the development of better systems for keeping in check tendencies toward environmental breakdown. It is the forthcoming task of the "science of economics" to recover, in the full sense of the term, a new lease on life. The age in which the science of economics has contributed to the waste of resources and even to the "population of the human spirit" is about to end. A new economic science must be poured not into an old wineskin but into a new one.

We shall in the future welcome an age in which the science of economics will contribute, from an overall global viewpoint, to the welfare of all the human race, going beyond the age in which economics often sought to serve only national interests of individual countries. This is also true in the field of economic policies. In order to achieve an overall global balance of economic policies under conditions of limited resources, it is required that there be a strengthening of United Nations organs and other economically related international organizations--a strengthening which requires the transfer of a portion of national sovereignity.

In particular, with respect to those developing countries which have problems of inadequate food resources, in order that development aid for promoting self-sufficiency in food be smoothly implemented, it will come to be seen as an urgent matter that much larger portion the national budgets of the industrially advanced and oil producing states be allocated for contribution to both United Nations organs and international financial institutions such as IBRD and IMF for redistribution with priority given to those developing states which are the most severely affected by the problems of resource scarcity.

Japan, which, among the major industrially advanced countries, has the most stringent limitations of energy and other natural resources, is in an excellent position to understand the viewpoint of those developing countries which are also resource-poor. Japan now stands at a crossroads of having to decide whether to simply sit by and watch the plight of the resource-poor developing countries with indifference--which could arise if Japan were to too easily, through agreements with resource-possessing countries--or, obtain the protection of a "resources umbrella"-or, on the other to feel and consider as its own the plight of these developing countries,to stand on the side of these other resource-poor countries, and to show an active and enthusiastic attitude in extending aid to these countries' efforts at liberating themselves from hunger and poverty.

It is possible that some of you will wonder how one can seriously suggest that Japan, itself affected by limited resources and faced with so many economic problems of its own, such as the downward turn in its rate of economic growth, should go so far as to try to look after the problems of other countries as well. However, the Japanese economy is and will continue to be compelled to identify itself more and more closely with the world economy as a whole.

And there is no doubt that there exists a historic opportunity for Japan, standing at a point of linkage between East Asian and Western civilization, to be the world's forerunner in effecting a transition, under conditions of limited resources, to a "post-industrial society".

In our global society, with its limited resources, it is likely that there will continue to be for some time sharp antagonisms and oppositions among the self-interests of various countries, but there is, on the other hand, an increasing necessity for cooperation among nations. This situation is indeed the historical reality of the "era of globalization" in which we must live, and it is true that Japan holds a great potential for helping open up this new age of international solidarity. And, it is being aware of just this mission that should be the spiritual backbone, which extends through all efforts of development assistance made by Japan.

If this epoch-making responsibility of Japan and all other countries to improve international cooperation and solidarity should fail, it is possible that opposing positions and struggles among various countries in connection with dwindling global resources might intensify, and it is even possible that the development of nuclear energy, which can be put to either peaceful or warlike purpose, might finally turn out to be more enemy than friend, with the human race becoming the victim of a nuclear war. The question of whether or not we can leave bahind the present "balance of fear" and correct the course of human society to more human and stable path, directed toward the building of a new world economic order of peace and prosperity--this question is the responsibility which we, who find ourselves in a "human society at the turning point," hold toward our children and future generations.

II. MACRO-ECONOMIC MULTI-NATION MODEL

Research Scope and Methodology

From the point of view described above, the authors have started with constructing a macro-economic multi-nation model, which will constitute the first level of the two level multi-nation model to be discussed in chapter 3. In this chapter the objective of this part of the study, and the details of the macro-economic model will be described.

The objective of the present study on this macro-economic model is to develop perspectives on the economic relations between the industrially advanced countries, and the developing countries of Asia in 1985, using a multi-nation model whose basic structures are rooted in a consideration of the "relationships of economic dependence" among these countries.

Various forecasts of economic growth and foreign trade in countries of the Asian region may be seen in published reports of studies undertaken by such organizations as the United Nations, Economic and Social Committee for Asia and the Pacific Region (ESCAP)(3), and the Ajia Keizai Kenkyujo (The Institute of Developing Economies) in Tokyo(4). However, attempts to analyze and forecast, by means of a multi-nation economic model, the relationships of mutual economic dependence among a number of different countries in the Asian region were pioneered by one of the present writers ten years ago (5)(6).

The basic idea behind the multi-nation model was taken from the industrial input-output table developed by Prof. W. Leontief (7). The present system model is, however, composed of a much more complex system structure.

In discussing various types of models, mention should be made of the "link project" undertaken in recent years with respect to macro-economic model for various countries. Research on "link project" is being furthered by various people and is based largely on the methodology developed by Prof. L. R. Klein [(8)]. Apart from these projects, Professors Mesarovic and Pestel, in carrying out research on a "world model", have produced a model which divides the world into 10 regions, with "sub-models" for each region. Here one sees an attempt to establish links through the flow of foreign trade [(9)]. As an attempt of a similar nature, a study is currently being carried out by Prof. Leontief in which the world is divided into several regions with industrial input-output tables for each region constituted from trade-matrices.

The multi-nation model which the present authors have been researching has been developed separately from the above-mentioned European and American studies, and has no direct relation to them. The outline of this model was presented at the IIASA World Modelling Symposium in October, 1974, and also at the West Berlin meeting of the Club of Rome [(10)]. The present model will be the core of a world economic model, research on which is currently being undertaken jointly by the present authors.

The geographic scope of the present study has been chosen to give attention primarily to Japan together with other industrially advanced countries and various developing countries in Asia. As hardly needs pointing out, the Asian developing countries have relationships of economic dependence not only with Japan but are also involved in economic relationships through governmental aid, private overseas investments and foreign trade in which the partners are most notably the United States, Canada, Australia, and various European nations. Also in recent years economic influence from China and the Soviet Union cannot be ignored. In relation to the above considerations, one might say that it would be more practical and realistic to look at matters concerned with the less developed countries of Asia as part of a model designed on a global level. However by taking the liberty of leaving a discussion of research derived from such a world model for another occasion, we have, in this study, limited the focus of concern to 14 developing countries (LDCs)in Asia and the 16 industrially advanced nations which are members of the DAC of the OECD.

Thus the total number of countries considered is 30, a size which permits relatively easy treatment of data by electronic computer techniques. The 16 industrially advanced countries are as follows: Japan, Australia, Canada, United States, Austria, Belgium, Denmark, France, West Germany, Italy, Holland, Norway, Portugal, Sweden Switzerland, and Great Britain. The 14 developing countries considered are: Burma, Taiwan, Hong Kong, India, Indonesia, Iran, South Korea, Malaysia, Pakistan, Bangladesh, Philippines, Singapore, Sri Lanka, and Thailand.

For purposes of linking the one-nation economic models for each of the 16 industrially advanced and the 14 developing countries in such a way as to analyze and develop perspectives on the economic relationships between the two groups, the best method is use of a "multi-nation model".

The particular "multi-nation model" used in the present study is a macro-economic model with its principal variables concerned with such things as production, consumption, investment, export-import, prices, wages, employment, official development assistance etc. It is composed of a system with approximately 3,000 equations in total.

We shall here proceed with some explanations of the model.

The Outline of the Model

The multi-nation macro-economic model used in the present study is composed of six "sub-sectors" as follows: (1) Production; (2) Expenditures on real gross domestic product; (3) Profits and wages; (4) Prices; (5) Expenditures on nominal gross domestic product; and (6) Official development assistance (ODA) and private overseas investment.

(1) Sub-sector Relating to Production

Factors which determine the potential for real gross domestic product in each country are availability of fixed capital, labor force, and technical levels. In our model, numerical values assigned to these factors are set in terms of total domestic production level per employed worker, availability of fixed capital per employed worker, and expenditures on research and development per employed worker (calculated as the cumulative total over the last 5 years). It must be stressed, however, that these factors determine what one might call each country's "potential supply capacity" only, since the actually achieved levels of domestic total production are determined as a result of additional relationships involving total demand. In other words, it is to be expected that these actual levels will be subject to ajustment through the prevailing characteristics of the gap between supply and demand. Thus, in our model, it is through controlled manipulation of total supply levels (as determined by production functions) through demand-supply adjustment factors that systems are induced for showing actual gross domestic product during a given period. In our system, a "production-oriented" model is used in the case of developing countries and a "demand-oriented" model is used in the case of the industrially advanced countries, although one might say it is a model which aims at an integration of the two. Now, let us inquire about the nature of the system for determining the structure of each country's expenditures on real gross domestic product.

(2) Sub-sector Relating to Expenditures on Gross Domestic Product at Constant Market Prices

The major factors determining the expenditures on gross domestic product in each country comprise the following: exports, imports, private consumption expenditure, government consumption expenditure, investment in plant and facilities, investment in housing, and investment in inventories.

The most important feature of this multi-nation model is the structure of its system for determining the imports and exports in each country's foreign trade. It is, first of all, a system which presupposes each country's economic growth to take place not as a completely self-reliant process but rather within a framework of relationships of mutual dependence given concrete form through foreign trade. In the case of industrially advanced countries, the flow of trade from country (i) to country (j) may be explained in terms of the gross domestic product of the importing country (j), the relative price competitiveness of the exporting country (i) as expressed in the ratio $P_e(i)/P_m(j)$, and the competitiveness ratio $P_m(j)/P_w(j)$ between imports and domestic products in the importing country. However, with respect to developing countries, it is most often the case that imports are restricted not so much by import elasticities with respect to income or prices, but rather by import capacity as such. In our model, import capacity over a given period is, in the case of developing countries, elucidated in relation to the export levels in the previous period and terms of trade (P_e/P_m) prevailing in the period.

Also, the model is so designed that the total exports of each of the countries considered therein are divided into exports going to these countries within the endogenous area of the model and exports going to the rest of the world. Total imports, on the other hand, are divided into three parts, i.e., those coming from countries within the endogenous scope of the model, those coming from the Middle Eastern and Arab countries, and those coming from other areas, thus making possible an analysis of the effects of the Middle Eastern and Arab nations' "oil strategies."

Expenditure on private consumption is mostly explained by income levels as in the ordinary Keynsian type model in the case of industrially advanced countries. However, the system is designed so as to obtain private consumption levels in the developing countries as residuals.

Expenditure on government consumption is taken in the model to be dependent on governmental revenue.

The gross fixed investment functions used to specify investment in plant and equipment differ as between the industrially advanced and developing countries. In the case of the industrially advanced countries, these functions specify a self-regulated sort of system in which investment in plant and equipment tends to increase in proportion to exports and corporate income, but tends to fall back with increases in proportion to exports and corporate income, but tends to fall back with increases in interest rates and unforeseen demand-supply imbalances. However, in the case of developing countries, domestic capital formation is elucidated in terms of increases in gross domestic product (which indicate expansion in market scale), as well as the inflow of official development aid and private direct overseas investments during a given period and export levels during that period, the two last-mentioned factors bearing an influence in raising the capacity for capital equipment imports during the succeeding period.

Apart from functions for investment in plant and equipment, our model includes separate functions for "investment in housing". Due to restrictions on the availability of data, these functions are employed mainly with respect to the industrially advanced countries only, although they are also applied to a part of developing countries as well, by way of exception.

Investment in inventories is elucidated by means of the commonly used "acceleration principle" and the methodology in this case does not differ from that used in ordinary econometric models.

The above are, in outline, the main structural factors relating to expenditures on gross domestic product, as they, in turn, determine the structure of total final demand. We have alreay referred to the fact that there come into play regulatory mechanisms for ensuring that "total supply", as induced from the production functions previsouly listed, be in balance with "total demand" as shown through the combination of these various main factors that make up the demand structure in the case of industrially advanced countries.

(3) Sub-sector Relating to Profits and Wages

We now shift our attention to the distribution aspect. The system for the distribution of the fruits of production, as expressed in terms of profits and wages, is as follows. "Profits," here defined as corporate income, rise with increases in gross domestic product, but are lowered by increases in interest rates. On the other hand "wages" (here, nominal wages) tend to rise with increases in actual labor productivity and increases in consumer prices, but the system structure presupposes that such wage rises will tend to be held back by any increase in the number of unemployed.

(4) Sub-sector Relating to Prices

The system structure for determining prices is more complex. This is because there is not just one type of price involved, but several. Account must be taken of wholesale prices, consumer's prices, capital equipment prices, export and import prices, as well as the implicit deflater of GDP, which could also be reasonably called one sort of "overall price index."

Firstly, wholesale prices are affected by a number of factors, including wage cost pressure (the pressure to push up prices in response to increases in labor productivity), the influence of import prices, the GDP deflater (ratio of nominal to real gross domestic product), and the index of currency turnover with respect to real income (ratio of index of total money supply to index of real gross domestic product).

Consumer's prices are influenced by such factors as wage levels during the current period, as well as by wholesale and import prices in addition to the currency turnover index during the preceding period. Prices for materials used in capital investments in plant and facilities are affected by investment ratios (proportion of gross domestic product going into capital investment in plant and facilities), as well as by movements in wholesale prices over the current period.

Prices of materials for investment in housing, in the same way as prices for capital equipment to be invested as plant and facilities, are strongly influenced by wage levels.

The price structure mechanisms operative with respect to export prices are different for the industrially advanced countries, the member countries of OPEC, and the group of other developing countries, respectively. Needless to say, the petroleum export prices enjoyed by the OPEC countries are determined not so much by any "market mechanism" as such, but rather through the operation of an artificially conceived cartel. On the other hand, export prices of the industrially advanced countries are determined under the influence of numerous and varied factors, including domestic wholesale prices during the preceding term, the GDP deflater, the state of international liquidity, and import price movements. Export prices in those developing countries which are integrated into the framework of market mechanisms prevailing in the world economy exhibit the same sensitivities.

Import prices in each country are calculated on a weighted average basis, taking into account the relative quantities and prices of imports from various regions and individual countries. One of the best and most useful features of the multi-nation model is its mechanism for determining these import prices, and through use of the model one may gain an understanding of the mechanisms by which inflation due to increases in the price of oil is propagated on an international scale.

(5) Sub-sector Relating to Structure of Expenditures on Gross Domestic Product at Current Market Prices

Once the various prices of the constituent factors relating to expenditures on gross domestic product in each country have been determined, the constituent factors relating may be mechanically deduced therefrom. By adding together all these structural factors, one arrives at a calculation of the nominal gross domestic product over a given period of time. The GDP deflater may be deduced from the two key values determined for the nominal and real gross domestic product, respectively.

(6) Sub-sector Relating to Official Development Aid and Private Overseas Investment

In the present model, the planned target for "official development assistance" (ODA) from the industrially advanced to the developing countries is expressed in terms of certain percentages of the gross domestic products of the countries of the former group. The sum of the official development assistance from the industrially advanced countries is then distributed among the developing countries according to certain temporarily fixed ratios which are likewise thought of as exogenous "policy parameters" set for the sake of official intergovernmental policy considerations.

The flow of private overseas investments from the industrially advanced to the developing countries is also treated in terms of certain percentages of GDP, but these ratios are thought of as exogenous controllable parameters, which are relatively subject to manipulation and change within the model structure. The same considerations hold for the distribution ratios respecting private overseas investments from the industrially advanced to the developing countries.

In the present model, while increases in official development assistance and private overseas investment are dependent primarily on income levels in the industrially advanced countries, it is expected that in this way any such increases are, conversely, capable of playing a useful role with respect to developing countries by making an addition of extra production factors acting to benefit whatever positive efforts are being undertaken by each of the latter countries with a view to increasing their own income. Thus, official development assistance and private overseas investment, together with foreign trade, form an important link in the interdependent relationships between the industrially advanced and the developing countries.

Forecast Scenarios and Discussion of Results Obtained

Using the multi-nation macro-economic model as explained above, we have made a forecast of the economic relationships between the 16 DAC members of the OECD and the 14 developing countries of Asia, taking 1970 as the base year and 1985 as the target year for the present study.

We carried out our analysis onwhat seemed to be the most likely scenario, although it must be admitted, of course, that the forecast results are subject to influence by possible unanticipated changes in such "exogenous variables", as the price of oil, each country's interest rate, money supply, etc. as well as by changes in aid-related policy parameters (e.g., ratio of official aid to GDP, ratios of aid apportionment, etc.).

While the actual movement in oil prices is known from 1970 through 1974, prices from 1975 onward were set, for purposes of the model, at the same levels prevailing in 1974. From the forecast results, one may see how the approximately 4-fold rise in the price of oil between 1973 and 1974 acts to push up each country's import prices, with the further effects of causing a worsening in many countries' international balance of payments and influencing wholesale and consumer's prices, thus accelerating inflation.

In the effort to cope with inflation, each country considered ih our model has in the period from 1973 to 1974 raised interest rates and reduced money supply, with the result that growth in GDP and capital investment in the major industrially advanced countries considered in our model has in every case registered "zero" or "minus" values. According to our forecast results, beginning in 1976 economic growth in the major industrially advanced countries is expected to return to a path of recovery.

If oil prices can be stabilized, each country can proceed in the direction of dampening inflation, but this in itself does not mean that pressures for price rises can be wholly stopped by such a development. Our forecast results also show, in this connection, that pressures for price increases, accelerated by the "oil shock," will, as a result of oil price stabilization, merely be lessened.

It was estimated in the model that, had it not been for the "oil shock," Japan's average yearly growth in GDP for the period 1970-1985 would have been approximately 9% in real terms. However, since minus or zero growth rates are continuing from 1974 into 1975, as a result of the world economic slump arising from the "oil shock," average yearly growth rate for the period 1970-1985 will not, according to our model's forecast results, hardly exceed 7%, even when one grants that the economy is expected to return to a path of recovery after 1976.

From the forecast results it may be seen what sort of impact this slowing down in Japan's growth rate over the period 1970-1985 is expected to produce with respect to the economic development of developing countries in Asia. According to the forecast, the slowdown in Japan's economic growth is expected to relay a considerable impact to the developing countries of Asia as a result of relative decreases in official development assistance and private overseas investment.

The strongest impact is received in the East Asia area by South Korea, Taiwan and Hong Kong, all of which have close economic relations with Japan, the United States and the other DAC countries. A case in point is the process by which the DAC countries' minus or zero economic growth in 1974 and 1975 seems to have been influential in producing an impact on the South Korean economy sufficient to bring down the growth rate of the latter to half its normal level. However, South Korean economic recovery has been rapid and it is expected that a yearly average growth rate of more than 8% in real terms can be maintained over the period 1975-1985. However, as a countervailing aspect of the high growth potential of the South Korean economy, one must recognize the fact that this high growth rate has brought about a serious deficit in that country's international balance of payments, making it even more dependent on the financial flow from the industrially advanced countries, from international bodies, as possibly from oil-producing Arab and Middle Eastern countries as well. In this respect, the world slump arising from the "oil shock" may be expected to have results which tend to oblige the South Korean economy, at the time it is engaged in efforts toward self-sustaining economic growth, to assume a larger debt burden.

The region receiving the second greatest impact (sustaining growth after the East Asia region) from the decrease in the DAC countries' economic growth rate is the Southeast Asia region. Since various countries of the region (Philippines, Thailand, Malaysia, Singapore, Indonesia, etc.) rely heavily on Japan, United States and the other DAC countries for marketing their exports, a "system structure" comes into being under which these countries, to a greater or lesser extent, receive an impact from reductions in the DAC countries, in particular, Japan's imports. However, in the case of Indonesia, it has been observed that this country's domestic economic development is not so greatly affected by export movements, and since the relative weight of Indonesia within the economy of the Southeast Asia region as a whole is high, the influence of economic slowdown of Japan and the United States, when seen in terms of statistics for the whole Southeast Asia region, appears to be considerably lower than with respect to the East Asia region. On the other hand, the growth rates of Malaysia and Singapore are very sensitive to export movements, and in the case of the Philippines and Thailand, whose foreign trade relies heavily on Japan as a trading partner, decreases in Japan's imports of course have a strong influence on these countries' international balance of payments.

In the South Asia region, whose relationships of economic reliance on Japan are relatively weak, the influence from the slowdown in Japan's economy is not so strongly felt. Trends for the region as a whole are greatly influenced by whatever trends prevail in India, and it should be mentioned in this regard that India has a low degree of economic reliance on the industrially advanced countries such as Japan and the United States. In considering the reasons for India's economic difficulties, purely domestic factors --for example, the stagnation in domestic total production linked to agricultural setbacks--take on far more importance.

It is expected that the relationships of economic dependence with respect to Japan and the other industrially advanced countries on the part of the Asian developing countries will, compared to the decade of the 1960's, become even stronger in the future. The growth of such relationships of economic dependence with respect to the industrially advanced countries on the part of developing countries in Asia presents a number of important problems for our consideration.

Firstly; there is the matter of the increase in what might be called the "international policy-related responsibilities" of the industrially advanced countries' economic growth. For if the industrially advanced market economy should continue to have an excessively low rate of growth, this slowdown in growth would, through the mechanisms of a slowdown in imports and a slowdown in the tempo of ongoing official development aid and private overseas investments, act to cause both increased instability in the Asian developing countries' international balance of payments and also a lowered tempo of economic growth in these countries.

On the other hand, should an excessively high rate of growth (higher than the real potential for productivity increases) continue over any extended period of time, this would merely aggravate the problem of the propagation of inflation from one country to another. Inflation in the industrially advnaced countries, by raising the prices of exports, necessarily pushes up the prices of imports in the developing countries of Asia, accelerating inflation in the latter. In this connection, rises in the industrially advanced countries' export prices also tend to worsen the terms of trade for the developing countries of Asia.

If the economies of Japan, the United States and the other DAC countries were to grow in such a way as to be accompanied by severe and repeated swings back and forth between the extremes of excessively low and excessively high growth rates, this would no doubt bring difficulties to the developing countries of Asia, and most especially to those in the East Asia region, as they attempt to meet the targets set in their own development plans for the achievement of sustained economic gorwth. The responsibilities borne by Japan, the United States and the other industrially advanced countries, economic growth are, in this respect, large.

Secondly, the increase in the degree of economic dependence with respect to the industrially advanced countries, in particular, Japan on the part of the developing countries of Asia may possibly give rise to further psychological and political frictions going beyond the realm of economics as such. In other words, the increase, especially in the industrially less developed countries, of what might be termed "the degree of inter-country sensitivity," as an accompaniment to increases in the degree of economic dependence, presents troublesome problems for both the industrially advanced and the developing countries. Such an increase in "the degree of inter-country sensitivity" might be said to occcur almost inevitably whenever relationships of mutual economic dependence between a given industrially advanced country and a given industrially less developed country are given added strength, but the fact nevertheless remains that the trend for this degree of sensibility to grow on the part of the industrially less developed countries gains additional strength in proportion as the relatioships involved exhibit any unilateral sort of dependence with respect to investment and foreign trade--any dependence which is liable, politically, to be taken as a relationship of subservience--directed toward the industrially advanced countries on the part of the developing countries.

This type of "inter-country sensitivity" can no doubt be controlled to a certain degree through bringing about changes in the structure of foreign trade between the Asian developing countries and the industrially advanced countries. The present structure of trade between the industrially advanced countries and the developing countries of Asia might be called a "vertical pattern" structure, in which the industrially advanced countries imports from the Asian developing countries tend to be foodstuffs and industrial raw materials, while its exports to these countries consist of either semi-processed products such as industrial plants, steel, fertilizers, constituent chemical products for synthetic fibers, etc., or such finished manufactured products as electrical apparatus, machinery, transport equipment and various types of machine parts for later assembly. This type of "vertical pattern" trade has the effect of raising the afore-mentioned "degree of inter-country sensitivity."

If, as the result, in part, of the industrially advanced countries' cooperation in the efforts of the Asian developing nations to achieve self-sufficiency in food and the basic infrastructures needed for industrialization, trade between the industrially advanced countries and the Asian developing countries should in the future come to be dominated by a "horizontal pattern" trade characterized by the mutual exchange of processed manufactured goods,such a development would be expected to have the effect of lowering the "degree of inter-country sensitivity" as referred to above.

As a condition for bringing about a situation in which the increasing closeness of the economic relations between the industrially advanced and the Asian developing countries should not nurture seeds of psychological and political disputation between our nations, an international economic reordering of such a type as would facilitate the Asian developing countries' changeover to "industrialized societies" appears to be needed.

III. AGRICULTURE AND INDUSTRY IN SELECTED ASIAN DEVELOPING COUNTRIES

South and Southeast Asian countries belong to one of the most densely populated regions in the world. If these countries were provided enough land and natural resources one could say that they had at least potentialities enough to satisfy the material needs of their people. If modern civilization were at its initial stage, one also could say that the tropical climate could give them the grace of God.

It is, however, tragic that the 'progress' of modern civilization has greatly changed their lives, mostly in ways which are seemingly desirable, but has also played the roles of potentially worsening the situation of the whole region. Spread of medical care, for instance, was effective in contributing to improving the mortality rate especially of children and has resulted in the high population growth rate of around 2.5%, which does not show any sign of decline. Such a high growth rate inevitably shapes the age structure toward a 'pyramid' type which means that considerable capital investment has to be diverted to formation of social capital such as education facilities and housing. This is a part of the causes of the stagnent condition of the economy in these countries, which in turn freezes the standard of living of people at a low level and encourages parents to have large families, thereby contributing further to population growth.

This interlinkage between stagnation of the economy and high population growth has been one of the most serious problems in most developing countries, especially those in Asia, and has prevented solution of other such problems including unemployment, under-employment, chronic malnutrition and illiteracy.

It then goes without saying that appropriate distribution of capital including investments from foreign countries and governmental aid is required to help in the development of the economy of these countries. Many development experts emphasize the necessity of agricultural development, because of many reasons. The main products of agriculture, foods, are the most essential elements for sustaining human life; agriculture absorbs unskilled labor; it supplies the raw materials to light industry, which is usually supposed to have a comparative advantage relative to advanced industrialized countries in the world market; it also supplies raw materials appropriate for export to advanced countries. We recognize there are many other reasons for stressing the importance of agricultural development, but at the same time we should see agricultural development of some Asian countries will be confronted by the basic barrier of available land and water resources.

To investigate the situation of this region the agricultural data (mainly of food production) of the five Asian countries (six after the establishment of Bandladesh), i.e. Thailand, Burma, India, Pakistan, Bangladesh and Sri Lanka, were studied. The growth of agricultural production is taken to be the growth of the total harvested area and the growth of average yield. Table 3.1 shows that in South Asian countries such as India and Pakistan the increase in the average yield occupies the dominant position in the growth of food production, while in Thailand and Burma the increase in the total harvested area is dominant. The latter countries still have potential arable land which may be developed in the future, and for them the easiest method for increasing food production is to expand arable land. On the other hand in the former countries almost all potentially arable being cultivated, and a strong emphasis was put on increase in the fertilizer input and adoption of new kinds of cereals.

This is seen from Table 3.2 and Fig. 3.1 which show that the growth rate of the total fertilizer input was very high in India and Pakistan, around 20% per year. It is not surprising that these countries could realize such high growth rates of fertilizer use, for the absolute value of fertilizer input to land was low. For instance even in 1970 the total fertilizer input per harvested hectare was 14 kilograms in India, 13 kilograms in Pakistan (including Bangladesh) but was about 480 kilograms in Japan, which is almost 20 times higher than in the former countries.

Is it then possible for these countries to maintain such high growth rate of fertilizer input in future? The authors' answer is unfavorable because of several reasons, the most serious one being the burden of fertilizer cost to ordinary farmers.

The ratio of the total fertilizer cost to gross agricultural product in various countries is shown in Table 3.3, which shows that the ratio of India and Pakistan is already of almost the same order as that of Japan. Moreover, the average income of an ordinary farmer in India and Pakistan is much lower than those of farmers in advanced countries. It is appropriate to consider that the real burden of fertilizer cost is much heavier to the farmers of low-income countries than to those of advanced countries.

In addition to that, the price of fertilizers has risen steeply in recent years, triggered by the rise in oil prices in 1973 and 1974. Taking the fact into account the ratio of fertilizer cost to GDP is fairly constant, almost 1%, it is natural to expect that the average growth rate of total fertilizer input in the long range future is almost proportional to that of GDP, say 5% or a little more.

Attention should then be again paid on the possibility of increase in the total harvested area. There may be three ways for attaining this purpose, i.e.

1. Increase in arable land
2. Increase in crop densities both in irrigated and non-irrigated area
3. Increase in irrigated land

The difficulty in 1. was already described before, but difficulties also lie in elsewhere. The crop density depends on various factors, but it is clear that increase in the crop density can be more easily realized for irrigated area than for non-irrigated area in the tropical climate, which has a long dry season. Fig. 3.2 shows the change of the average crop density in the 1960's, and shows that its growth rate was very low. One of the reasons is the low growth rate of irrigation in India and Pakistan shown in Table 3.2.

Serious, however, is not only the tempo of the expansion of irrigated land but the high cost of irrigation. The data on estimation of the cost of land development, irrigation and drainage is very scarce, except FAO estimate in 1969.[12] The data are updated in 1970 prices and shown in Table 3.4. It is seen that the cost of irrigation is much higher than the cost of land development, and so that it will be a high barrier to overcome.

There are a few ways to measure capital efficiency, but we used a simple equation,

$$\text{capital coefficient} = \frac{\Sigma \text{ Increase in Production}}{\Sigma \text{ Investment Cost}} \qquad (1)$$

Summation is taken with regard to time. This definition is a little different from the ordinary definition of capital coefficient, but it is useful to see how the capital works. According to the statistical data, the estimated capital coefficient defined in (1) is between 1 and 2 in

India, Pakistan, Sri Lanka, Burma and Thailand in the late 1960's. This small value was, however, especially in the first two countries, not brought about by efficient use of investment but by rapid increase in fertilizer input, as explained before, The authors are afraid that the capital efficiency will rapidly decline in these countries when the growth of agricultural production which is required to secure food for rapidly increasing populations will depend not on the growth of fertilizer input but on investment in irrigation. In other words, putting emphasis on agricultural development was once considered to lead to economic development, but will possibly become a barrier to it.

Industrial and Agriculture

It has been widely understood that economic development of a country depends heavily on industrialization, of which the major motive force is the high elasticity of demands for industrial goods with regard to per capita income, which actually means the equivalence of the 'modern civilized life' and 'life of material affluence' at least in the past. In recent years reflections on overconsumption of resources in advanced industrial countries stimulated efforts to change the character of the modern society, but it should also be recognized that the situation of most developing countries is extremely distant from the stage of talking about "post-industrial society". A greater part of demand for industrial goods in developing countries has been satisfied by the import from advanced industrialized countries, which has been a main cause of worsening the international trade balance. Industrialization has been one of the most important targets of developing countries, but it is true that such industrialization, usually with the help of foreign investments, has brought about various side-effects which disturbed a balanced economic growth of the country concerned e.g., introduction of luxurious industrial goods such as TV sets, automobiles, and refrigerators, widening the gap between employers and employees as happened in the past history of the advanced countries, and shortage of labor intensive industries which may have a comparative advantage in the world market.

As has been frequently said industrialization requires a huge amount of investment, which has been also a problem because it has played a role of worsening the international balance of payments position. The capital coefficient the authors defined above is a good measure to use when discussing this point. In Table 3.5, these values for various advanced industrialized countries are listed. The exact equation used for estimating the marginal capital eo-efficient β is as follows;

$$\sum_{t'=t_0}^{t-1} \Delta S_p^*(t') = \beta(V_{(t)}^* - V_{(t_0)}) + \eta(t); t = t_0 + 1, \cdots, T \qquad (2)$$

where $V_{(t)}$ is the production of value added in year t, $\Delta S^*_{p(t)}$ the capital investment during year t and $\eta(t)$ the noise term (all are in constant prices). The simplest least square method is applied to estimate β . Although values of β differ from country to country, it lies between 1 and 3, which is a little higher than the β of agriculture for most of South and Southeast Asian countries in the late sixties. The estimation of β of manufacturing industry in these developing countries is hard because of difficulty of atquiring accurate data, but β of total of the sectors other than agriculture can be estimated from UN statistics. The results show that β 's in Pakistan (including Bangladesh), Sri Lanka and Thailand are a little higher than those of manufacturing industries in advanced industrialized countries, while the β in India is the highest, between 6 and 8. The values calculated in the above does not correspond to the β 's of manufacturing industries, but considering that the β of manufacturing industry is usually of the same order as that of other sctors including service sectors (for instance inPakistan the β of the former is around 4.5 and the β of the latter is 3.5.), it can be said that the capital coefficients of the manufacturingindustries in these Asian developing countries are a little higher than those in advanced industrialized countries.

There are several causes of such a low capital efficiency of manufacturing industries, among which are underutilization of factory equipment and in India, investment biases favoring capital intensive sectors such as steel industry. As the insustrialization will go on, however, it will be improved and will decline to the values of those in advanced countries ,i.e. around 2 or 3.

The preceding discussion tells that the capital coefficient of agriculture in South Asian countries will rise mainly because of large investments in irrigation necessary for securing food supply to rapidly growing population, while the capital coefficient of manufacturing industry will decline. In the foreseeable future the former will exceed the latter. In other wordsindustrialization will become more effective in capital use in South Asian countries than development of agriculture. As described in the first part of this chapter many development experts have stressed the importance of agricultural development in Asian developing countries and the authors do not intend to oppose it. Our intention is to point out that the industrialization in South Asian countries may have the advantage of effective capital use and then accerelate economic development of these countries, which thereby will accerelate agricultural development. The use of capital investmet in industry, harmonized with agricultural development may gain priority in the future policy of these countries, and the authors are intending to study on this aspect by the use of a two-level multi-nation model, of which the structure will be described in the next chapter.

Table 3.1 Growth Rates[*1] of Food Production and Its Components in the Five Asian Countries

	1961 - 1970			1965 - 1970		
	Harvested area	Average yield[*2]	Total Production[*2]	Harvested area	Average yield[*2]	Total Production[*2]
Thailand	3.4%	2.1%	5.5%	4.4%	1.4%	5.8%
Burma	1.6	0.6	2.2	0.4	0.2	0.6
India	0.8	2.7	3.5	1.8	4.5	6.3
Pakistan & Bangladesh	2.0	1.9	3.9	1.8	3.1	4.9
Sri Lanka	3.5	1.7	5.2	7.4	3.7	11.1

*1 For the sake of decomposing production elements the growth rate shown here is simply the difference of the corresponding variables in the initial year and in the termination year, divided by the time length. Average growth rates of these variables estimated by the statistical method are a little different from the values in the table.

*2 In terms of calories.

Source : FAO Production Yearbook.

Table 3.2 Growth Rates[*1] of Various Elements in Agriculture in the Five Asian Countries

	Crop density	Data year	Arable land	Data year	Irrigated land	Data year
Thailand	1.8%	'61-'70	2.8%	'60-'70	7.7%	'61-'70
Burma	-2.1	'61-'70	3.4	'61-'70	5.1	'61-'70
India	0.8	'61-'70	0.3	'61-'70	2.7	'61-'70
Pakistan & Bangladesh	1.0	'61-'70	1.9	'61-'67	0.5	'61-'70
Sri Lanka	-3.0	'61-'70	3.3	'61-'70	2.8	'61-'70

*1 Averaged during the data period, so they do not correspond to those of Table 3.1

Source: FAO Production Yearbook.

Table 3.3. Cost of Fertilizer in 1970

	Fertilizer cost / GAP (%)	GAP (US$) per capita	Fertilizer per harvested area (kg/ha)
Japan	7.4	642	486.1
India	5.7	61	14.1
Pakistan	7.0	79	12.7
Sri Lanka	3.5	108	107.2
Burma	1.5	46	3.0
Thailand	0.3	73	8.9

*GAP = Gross Agricultural Product.

Source: FAO, Production Yearbook, The State of Food and Agriculture 1973, p.219.

Table 3.4 Cost for Land Development and Irrigation (1970 Price, $/ha)

	Land Development Cost	Irrigation Cost
Thailand	125	720
India	50	1780
Pakistan (and Bangladesh)	240	930
Sri Lanka	360	2770

*1 FAO IWP estimate is on the basis of 1962 price. Since the investment cost is composed mainly of labor cost, the cost should be modified by the labor cost deflator, of which, however, no data are available. So the authors used temporarily GNP deflator.

*2 The cost listed in the table is the average of the FAO plan until 1985.

Source: FAO Provisional Indicative World Plan, 1969.

Table 3.5 Capital Coefficients of Manufacturing Industries of Various Countries

	Capital coefficient	Data year	γ (correlation coefficient)
Canada	2.04	'60-'71	0.967
Japan	1.20	'60-'71	0.992
U.S.A.	1.33	'60-'71	0.917
Belgium	2.94	'60-'71	0.985
Sweden	2.70	'63-'71	0.994
West Germany	1.39	'63-'71	0.971
Italy	3.23	'63-'71	0.975

Source: UN, The Growth of World Industry.

Fig. 3.1

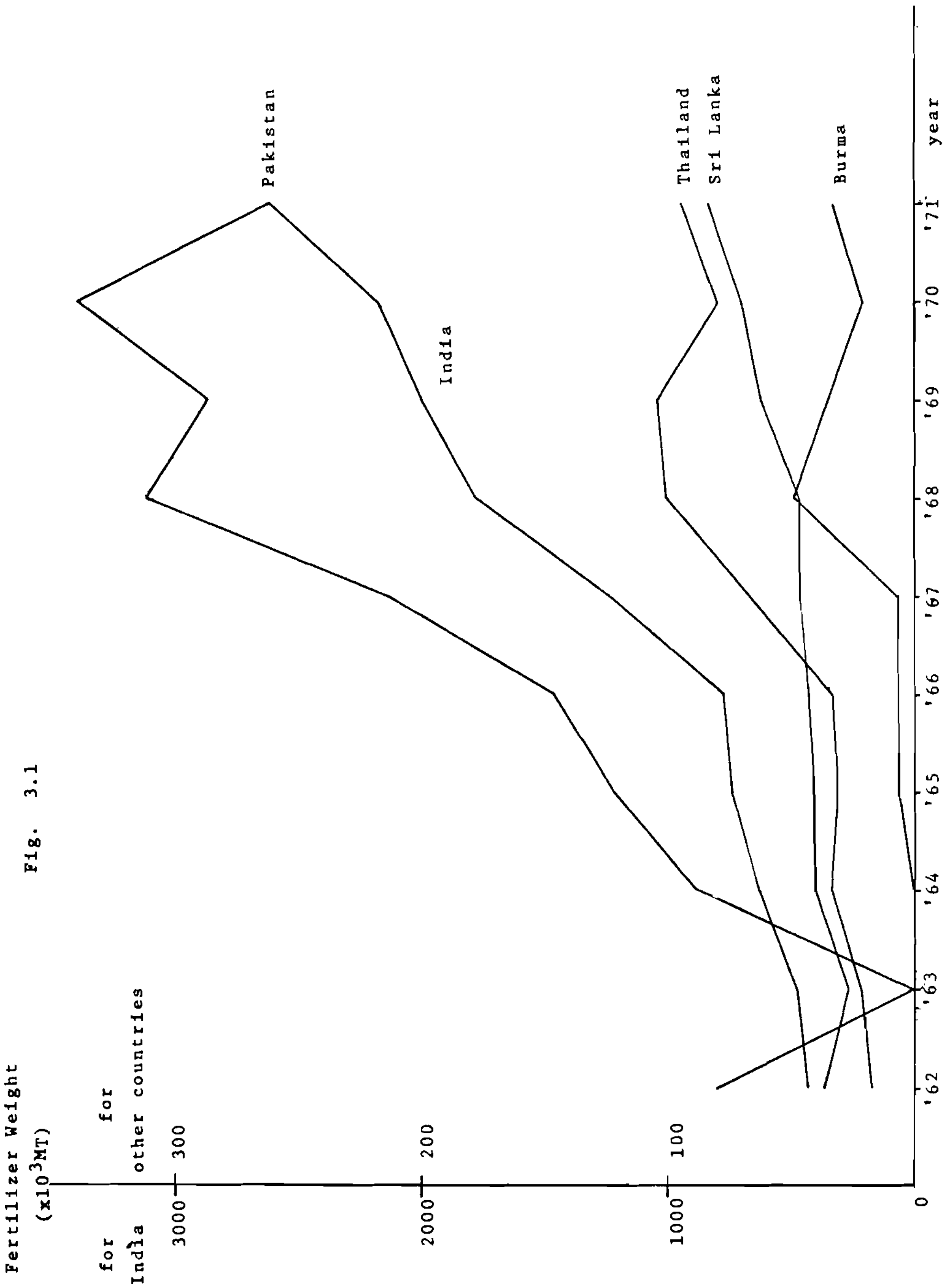
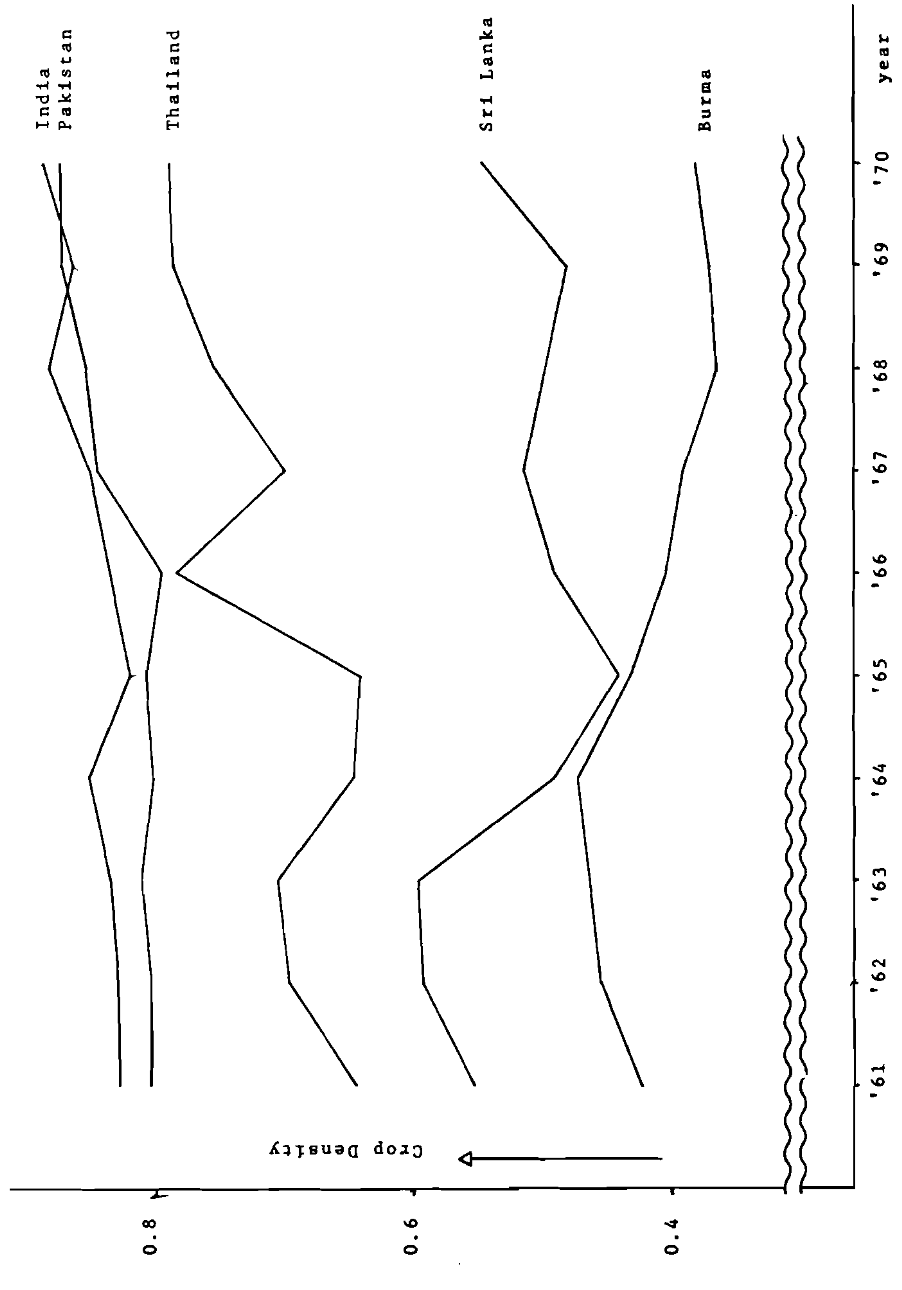

Fertilizer Weight
(x10³MT)
for India
for other countries
3000
2000
1000
300
200
100
0
'62
'63
'64
'65
'66
'67
'68
'69
'70
'71
year
Pakistan
India
Thailand
Sri Lanka
Burma

Fig. 3.2 Crop Density in the Selected Asian Developing Countries



IV. STRUCTURE OF A TWO LEVEL MULTI-NATION MODEL

Recent escalation of the consciousness of the global society has stimulated research on the world models which may clarify the behavior of complex international relations as well as tendencies for change of the states of global resources. The 'World Dynamics' or 'The Limits of Growth' Model originally developed by Forrester[13] may be the one of the simplest types in the sense that the world was dealt with as a whole in the model, but there have been or are being developed many other kinds of models which may be classified into the category of the world model. A. Bottomley[14] listed of eleven such models but there are probably many others. For instance a few models not described in his list have been developed in Japan, such as the world trade model by Shishido[15] and the world food model developed by Mitsubishi Research Institute[16]. Almost all of these models are similar in the sense that the world is divided into several blocks or nations, but they are basically divided into three categories:

1. Multi-nation and/or block, one specific sector model
2. Multi-nation and/or block, multi-sector model
3. Macro multi-nation and/or block model combined with sectionized nation and/or block models.

The first of these types includes various kinds of the world energy models, and world food and agriculture models such as the Mitsubishi model. On the other hand, the well-known LINK model organized by Klein[8] and UNEP model by Leontief[17] are typical examples of the second type. Bariloche's model may be categorized as being of this type, but is a little different from others in that international trade does not play an effective role in the model. In principle a model of this type is the best suited to investigate complexly entwined relations between nations and sectors, but the model may become too large in scale, and the model builders have to exert much efforts to avoid propagating error from one part to the whole model as time goes on. Another problem potentially unavoidable when building models of this type is the difficulty in gathering the data on the micro-structure of industries in each nation and/or block, such as those of the input-output tables properly compiled in a unified form. A. Bottomley also showed a list of the input-output tables available to him, and the authors also have many tables of various countries, but anyone engaged in construction of these models knows how hard it is to prepare appropriate input-output tables for the nations and/or blocks to be covered in his world model. The authors once tried to construct a world model of this type, aiming at clarifying the pattern of the international division of labor which is normative in the sense that the first order priority is given to development of developing countries balanced with various economic and physical requirements[18]. The authors could derive qualitative findings from the model, but came to a conclusion that it might not tell more than these without sufficient data on the input-output tables in a greater part of the regions in the world. This rather disappointing conclusion leads us inevitably to restart construction of the world model of other type, i.e. the third type.

Models of the third type are relatively rare. The Mesarovic-Pestel Model[9] is basically of this type, but to the extent of the authors' knowledge, details of the structure of connecting mcaro-level and micro-level have not been published yet. The present authors propose a model, which has a macro-economic multi-nation and/or block model linked with multi-sector models of the nations or blocks concerned. In other wor ds the international economic relations through which the behavior of a country's economy influences those of other countries, are expressed in sectionized terms.

The advantage of adopting models of this type is to decrease the scale and number of variables as much as possible, while retaining the objective of investigating the effects of choice of various development patterns in the selected nations such as South and Southeast Asian developing countries on these nations and the rest of the world. As a first step towards construction of such a model the authors decided to construct a two level model as such;

a) A macro-economic multi-nation model consisting of thirty countries, as expressed in chapter 2.

b) Three sector production models of selected countries, namely India, Pakistan and Bangladesh, Sri Lanka and Thailand.

The connection between a) and b) is temporarily only through the gross domestic product and export, as is shown in Fig.4.1. The outline of this part is described below.

1) Production part

From the macro-economic multi-nation model described in chapter 2 (let it be called MNM) the total investment in constant prices, Δs_p^* is given, distribution of Δs_p^* into agricultural, manufacturing and other sectors are determined from the scenario the authors construct. There may be several scenarios to be adopted, for instance, one in which the strong emphasis is put on land development and irrigation in order to increase food production, one in which the past trend continues, and so on. It is stressed that the objective of the model building is not to see what will be in the future but to see what should be done as national and international policy.

Once given the distribution of investments in three sectors the gross domestic product of each sector is calculated. The details are described in Appendix 2. The result of the calculation, ** is then replaced into the corresponding equation in MNM.

2) Export part

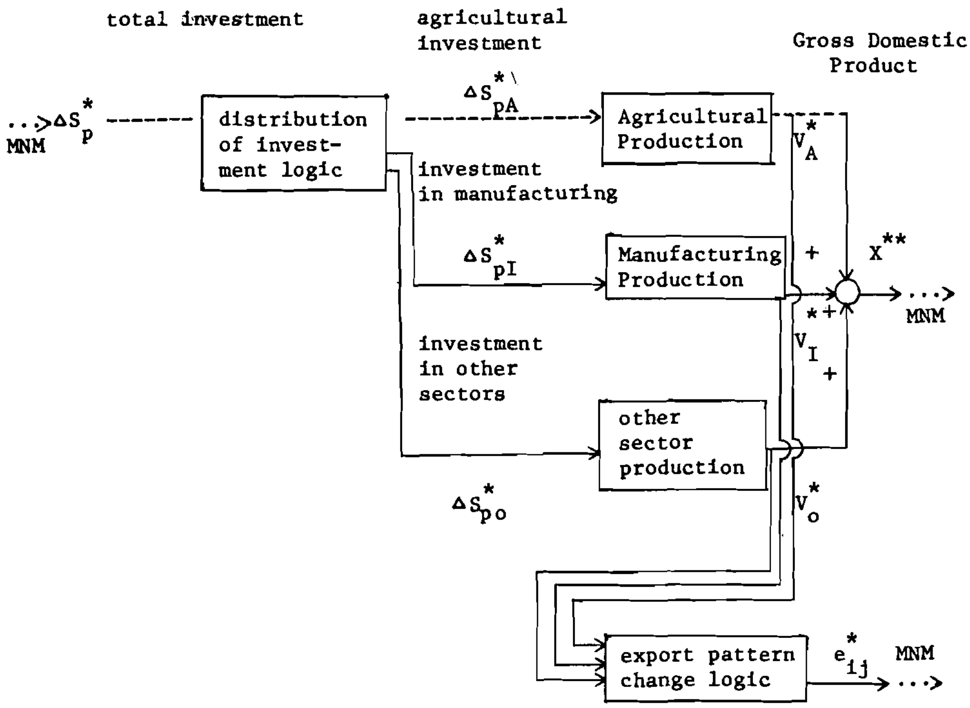
In MNM the export from a nation to other nations is denoted by e^{*}_{ij} (from ith nation to jth nation). This e^{*}_{ij} is a function of various variables, and can be considered as extrapolation of the past trend of export pattern, (not only in macro-scopic terms but also in microscopic terms) but when one of the scenarios as described above is adopted the content of the gross domestic product will change and trigger the change in e^{*}_{ij}, which should be taken into account.

The basic principle in modifying e^{*}_{ij} is that the change in e^{*}_{ij} is the sum of changes of the share of agriculture and manufacturing industries in GDP times ratio of goods in each sector to the total export. The details are described also in Appendix 2.

3) Other part

There may be several elements which may change not through the macroscopic structure when the industrial pattern changes. Export price index p_e is one of such variables. The authors are continuing to investigate other possibilities of change of macro variables due to change in micro structure including p_e.

Fig. 4.1 Sectionized Model of a Nation connected to Macro-Economic Multi-Nation Model (MNM)



V. DIRECTION OF FURTHER RESEARCH

The construction of the two level multi-nation model proposed in the preceding chapter is now under way, and the authors have the following future research plan.

1) Construction of a two-level multi-nation model, of which the lower level consists of not only the Asian developing countries selected at the first stage but other countries in each of which agricultural production plays an important role in national and/or international economy. United States and Japan are the candidates from the side of advanced industrialized countries.

2) Addition of the mechanism into the above model, with which the normative pattern of international division of labor mainly in manufacturing industries can be investigated, taking various natural and social constraints specific to each country into account.

   At the first step the second level model consists only of three sectors, of which the second sector, manufacturing industry, occupies the dominant position in the international trade. Construction of the new world economic order described in Chapter 1 inevitably requires change in the present state of international division of labor, especially in industry sectors. The authors plan to divide the manufacturing industry sectors into 10 to 15 subsectors, and apply the mathematical planning methodology (possibly LP) to find the change of production pattern of these sectors of various countries which satisfy various constraints concerned with capital, labor, labor quality, environment, and so on. The authors already started setting of the model framework and gathering of data input-output tables, census data on labor quality in various industry sectors, time series data of trade flow, etc.), in parallel with the present work.

3) Expansion of the multi-nation model to the world model.

The present multi-nation model consists of only thirty countries i.e., 16 industrially advanced and 14 developing Asian countries, and the authors intend to expand the model to the worldwide one. Accumulation of the data for this purpose is also already going on.

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APPENDIX 1.

Macro Economic Multi-Nation Model

1. Model Equations

I. Production

1. $$\left(\frac{x^{**}}{l}\right) = \bar{z}_a \left\{ \alpha + \beta \left(\frac{\sum_{t}^{-4} \Delta s^{*}_{p}}{l}\right) + \gamma \left(\frac{\sum_{t}^{-4} r^{*}_{d}}{l}\right) \right\} + \bar{z}_b \left\{ \alpha + \beta \left(\frac{\sum_{t}^{-4} \Delta s^{*}_{p}}{l}\right) + \gamma \left(\frac{\sum_{t}^{-4} \bar{r}^{*}_{dm}}{l}\right) \right\}$$

2. $r^{*}_{d} = \alpha + \beta\, x^{*}_{-1}$

3. $d^{*}_{p} = \alpha + \beta\, s^{*}_{p-1}$

4. $x^{*} = \psi \left[\left(\frac{x^{**}}{l}\right) \cdot l \right]$ (ψ is endogenously determined for DAC)

5. $s^{*}_{p} = s^{*}_{p-1} + \Delta s^{*}_{p} - d^{*}_{p}$

6. $l = (1 - \bar{u})\, \bar{l}_{cs}$

$\bar{z}_a = 1$, $\bar{z}_b = 0$ (for DAC) DAC: Industrially developed countries

$\bar{z}_a = 0$, $\bar{z}_b = 1$ (for LDC) LDC: Developing countries

II. Expenditure on GDP (at constant prices)

1. $e^*_{(i,j)} = \bar{z}_a \{ A + B\, x^*_{(j)_{-1}} \overset{\Theta}{+} \Gamma \left[\frac{P_{e(i)}}{P_{m(j)}}\right]_{-1} \overset{\Theta}{+} \Xi \left[\frac{\bar{t}_{m(j)} \cdot P_{m(j)}}{P_{w(j)}}\right]_{-1} \} + \bar{z}_b \{ A$

$+ B\, [e^*_{(j)-1} + (\Sigma o_{da(i,j)} + \Sigma \Delta s_{op(i,j)} + \bar{a}_m + \bar{a}_c)_{-1}] \cdot \left[\frac{P_{e(j)}}{P_{m(j)}}\right]_{-1} + \Gamma\, x^*_{(j)_{-1}}$

2. $f^*_o = \alpha + \beta\, \hat{\hat{T}}^*_o$ ($\bar{z}$ relates to importing countries(j).)

3. $m^*_o = \alpha + \beta\, x^*_{-1}$

4. $c^* = \bar{z}_a[\alpha + \beta\, x^* + \gamma\, c^*_{-1}] + \bar{z}_b[x^* - e^* + m^* - g^* - \Delta s^*_p - \Delta s^*_h - \Delta s^*_i]$

5. $g^* = \alpha + \beta\, r^*$

6. $r^* = \alpha + \beta\, x^*_{-1}$

7. $\Delta s^*_p = \bar{z}_a \cdot \Lambda \{\alpha + \beta\, y^*_{c-1} + \gamma\, e^*_{-1} \overset{\Theta}{+} \delta\, \bar{i}_{-1} \overset{\Theta}{+} \varepsilon\, [o_{da} + \Delta s_{op}]_{-1} \}$

$+ \bar{z}_b \cdot \Lambda \{ \alpha + \beta\, x^*_{-1} + \gamma\, [e^*_{-1} + (\overline{\sum_i o_{da(i,j)}} + \sum_i \Delta s_{op(i,j)} + \bar{a}_m$

$+ \bar{a}_c)_{-1}] \cdot \left[\frac{P_e}{P_m}\right]_{-1} \}$ ($\Lambda = f(\psi)$ for DAC)

8. $\Delta s^*_h = \alpha + \beta\, x^* \overset{\Theta}{+} \gamma\, p_{h-1} \overset{\Theta}{+} \delta\, \bar{i}_{-1}$

9. $\Delta s^*_i = \alpha + \beta\, x^* + \gamma\, (x^* - x^*_{-1}) \overset{\Theta}{+} \delta\, \bar{i}_{-1}$

10. $e^* = \sum_j e^*_{(i,j)} + f^*_o$

11. $m^* = \sum_i e^*_{(i,j)} + m^*_o + \bar{m}^*_E$

12. $x^* = e^* - m^* + c^* + g^* + \Delta s^*_p + \Delta s^*_h + \Delta s^*_i$ (for DAC)

III. Profit-Wage

1. $y^*_c = \alpha + \beta\, x^* \overset{\ominus}{+} \gamma\, \bar{i}_{-1}$

2. $\omega = \alpha + \beta\, p_{c-1} + \gamma\, p_y \overset{\ominus}{+} \delta\, \bar{u}_{-1}$

3. $p_y = (\frac{x^*}{l}) / (\frac{x^*_o}{l_o})$

IV. Prices

1. $p_w = \alpha + \beta\, p_{m-1} + \gamma\, [\frac{\omega}{p_y}] + \delta\, (\frac{x}{x^*})_{-1} + \epsilon\, i_{v-1}$

2. $p_c = \alpha + \beta\, p_{w-1} + \gamma\, \omega + \delta\, p_{m-1} + \epsilon\, i_{v-1}$

3. $p_{cg} = \alpha + \beta\, p_{w-1} + \gamma\, \omega + \delta\, i_{v-1}$

4. $p_i = \alpha + \beta\, p_w + \gamma\, (\frac{\Delta s^*_p}{x^*})$

5. $p_h = \alpha + \beta\, p_i + \gamma\, \omega$

6. $p_e = \bar{z}_a \{ \alpha + \beta\, p_w + \gamma\, \hat{\bar{i}}_{qw-1} + \delta\, p_{m-1} + \epsilon\, (\frac{x}{x^*})_{-1} \}$
$+ \bar{z}_e \{ \alpha + \beta\, p_w + \gamma\, \hat{\bar{i}}_{qw-1} + \delta\, p_{m-1} + \epsilon\, \hat{\bar{p}}_{ec} \} + \bar{z}_o \cdot \{ \hat{\bar{p}}_{eE} \}$

($\bar{z}$ relates to exporting country (i).)

7. $p_m = \{ \sum_i [p_{e(i)} \cdot e^*_{(i,j)}] + \hat{\bar{p}}_{eo} \cdot m^*_o + \hat{\bar{p}}_{eE} \cdot \bar{m}^*_E \} / [\sum_i e^*_{(i,j)} + m^*_o + \bar{m}^*_E]$

8. $p = \frac{x}{x^*}$

A 9. $i_v = (\frac{\bar{m}_s}{\bar{m}_{so}}) / (\frac{x^*}{x^*_o})$

$\bar{z}_a = 1,\ z_e = 0,\ z_o = 0$ (for DAC)

$z_a = 0,\ z_e = 1,\ z_o = 0$ (for LDC excluding OPEC)

$z_a = 0,\ z_e = 0,\ z_o = 1$ (for OPEC)

V. Expenditure on GDP (at current prices)

1. $e = p_e \cdot e^*$

2. $m = p_m \cdot m^*$

3. $c = p_c \cdot c^*$

4. $g = p_{cg} \cdot g^*$

5. $\Delta s_p = p_i \cdot \Delta s^*_p$

6. $\Delta s_h = p_h \cdot \Delta s^*_h$

7. $\Delta s_i = p_w \cdot \Delta s^*_i$

8. $x \doteq e - m + c + g + \Delta s_p + \Delta s_h + \Delta s_i$

9. $b = e - m + \bar{j}$

VI. Official Development Assistance and Private Overseas Investment

1. $o_{da} = \bar{\Pi} . x^*$

2. $\Delta s_{op} = \bar{\Theta} \cdot x^*$

3. $\sum_i o_{da(i,j)} = \bar{\Omega} \cdot o_{da}$

4. $\sum_i \Delta s_{op(i,j)} = \bar{K} \cdot \Delta s_{op}$

5. $s_{op} = s_{op-1} + \Delta s_{op} - \bar{f}_d$

APPENDIX 2

Equiations for the economy of selected nations

1) Production Sector

Agriculture

$$\Delta S^*_{PD} = \begin{cases} \Delta S^*_{PA} - \Delta S^*_{PR} & \text{for Thailand} \\ \alpha_D \Delta S^*_P & \text{for India, Pakistan and Bangladesh, Sri Lanka} \end{cases} \quad (A4.1)$$

$$\Delta S^*_{PR} = \begin{cases} \alpha_D \Delta S^*_P & \text{for Thailand} \\ \Delta S^*_{PA} - \Delta S^*_{PD} & \text{for India, Pakistan and Bangladesh, Sri Lanka} \end{cases} \quad (A4.2)$$

$$A_D = A_{D,-1} + \frac{1}{C_D}\Delta S^*_{PD,-1} - \frac{1}{C_R}\Delta S^*_{PR,-1} \quad (A4.3)$$

$$A_R = A_{R,-1} + \frac{1}{C_R}\Delta S^*_{PR,-1} \quad (A4.4)$$

$$\overline{P}_D = K_D \cdot A_D \cdot P_D \quad (A4.5)$$

$$\overline{P}_R = K_R \cdot A_R \cdot P_R \quad (A4.6)$$

$$V^*_A = F_A \cdot (\overline{P}_D + \overline{P}_R) \quad (A4.7)$$

$$P_D = f_D(F/(K_D A_D + K_R A_R)) \quad (A4.8)$$

$$P_R = f_A(F/(K_D A_D + K_R A_R)) \quad (A4.9)$$

A_D ; arable land without irrigation (ha)

A_R ; irrigated arable land (ha)

C_D ; unit investment cost for land development in constant prices (\$/ha)

C_R ; unit investment cost for irrigation in constant prices .(\$/ha)

K_D ; crop density for A_D

K_R ; crop density for A_R

P_D ; yield of A_D in terms of calories (Cal/ha)

P_R ; yield of A_R in terms of calories (Cal/ha)

F_A ; price - calory converter

ΔS^*_{PD} ; investment for land development

ΔS^*_{PR} ; investment for irrigation

V^*_A ; gross domestic product of agriculture

F ; total input of fertilizers (t)

f_D, f_A are the table functions determined from the past data. F is determined from the given value of the elasticity to GDP, between 1.0 and 1.5.

Manufacturing Industry

$$V^*_I = \frac{1}{\beta_I} \Delta S^*_{PI} + V^*_{I,-1} \qquad \text{(A4.10)}$$

β_I ; capital coefficient defined in chapter 3

V^*_I; gross domestic product of manufacturing industry

β_I is chosen as the same as the average of β_I of advanced industrial countries for Thailand, Pakistan and Bangladesh and Sri Lanka, but as a function of time slowly going down from 10 to the average of β_I of advanced industrial countries.

Other Sectors

$$V^*_R = \beta_R \cdot \Delta S^*_{po} + V^*_{R,-1} \qquad \text{(A4.11)}$$

2) Export Sector

$$e^*_{ij} = oe^*_{ij} + \Delta e^*_{ij} \qquad \text{(A4.12)}$$

$$\Delta e^{*}_{ij} = ({}^{o}g_{i,-1} - g_{i,-1})(V_{A,i,-1} + V_{I,i,-1})(r^{I}_{ij} - r^{A}_{ij})K_{i}$$

for export of the selected Asian developing countries (A4.13)

$$({}^{o}g_{j,-1} - g_{j,-1})(V_{A,j,-1} + V_{I,j,-1}) R_{i,-1}U_{i}$$

for import of the selected Asian developing countries from main food exporting countries (A4.14)

$$R_i = \frac{\sum_j e^{*F}_{ij}}{\sum_{i,j} e^{*F}_{ij}} \quad \text{(A4.15)}$$

$$g_i = \frac{V_A}{V_A + V_I} \quad \text{(A4.16)}$$

$$e^{*F}_{ij} = e^{*}_{ij} - oe^{*}_{ij}(1 - r^{F}_{ij}(t)) \quad \text{(A4.17)}$$

e^{*}_{ij}; the export from i-th country to j-th country

oe^{*}_{ij} ; the forecast of e^{*}_{ij} from one-level multi-nation model

Δe^{*}_{ij} ; the change of the export due to the change of structure of the gross domestic product of the selected Asian developing countries

e^{*F}_{ij} ; the food export from i-th country to j-th country

$o\,g_i$; the extrapolated value of the past trend of g_i

K_i ; the extrapolated value of the past trend of the ratio of the total export of i-th country to the sum of the gross domestic product of agriculture and manufacturing industry.

r^{I}_{ij} ; the ratio of the export of industrial goods from i-th country to j-th country to the total export between two countries

r^{A}_{ij} ; the ratio of the export of agricultural goods from i-th country to j-th country to the total export between two countries.

r^{F}_{ij} ; the ratio of export of food from i-th country to j-th country to the total export between these two countries.

R_i ; the ratio of food export of i-th country to the food export of the whole food exporting countries.

U_i ; the ratio of real food import to the potential demand for food import

Explanation of Symbols

x	A column vector of n element which denotes gross domestic product (at current market prices) of n countries within the endogenous region.
x^*	" gross domestic product at constant prices.
x^{**}	" potential gross domestic product at constant prices.
$e^*_{(i,j)}$	An element of $e^*_{(i,j)}$ matrix which denotes exports from country i to country j (at constant prices).
f^*_o	A column vector of n element which denotes each country's exports outside the region (at constant prices).
e	A column vector of n element which denotes exports of goods and services (at current prices).
e^*	" exports of goods and services (at constant prices).
m	" imports of goods and services (at current prices).
m^*	" imports of goods and services (at constant prices).
m^*_o	" imports of goods from the rest of the world (at constant prices).
c	" private final consumption expenditure (at current prices).
c^*	" " (at constant prices).
g	" government final consumption expenditure (at current prices).
g^*	" " (at constant prices).
r^*	" government current revenue (at constant prices).
Δs_h	" housing investment (at current prices).
Δs^*_h	" " (at constant prices).
Δs_p	" non-housing investment (at current prices).
Δs^*_p	" " (at constant prices).
Δs_i	" increase in stocks (at current prices).
Δs^*_i	" " (at constant prices).

s^*_p	A column vector of n element which denotes fixed capital stocks (at constant prices).
d^*_p	" depreciation of fixed capital (at constant prices)
r^*_d	" research and development expenses (at constant prices
y^*_c	" corporate profit (at constant prices).
l	" employment (in terms of man-hour).
$\bar{l}_{cs}$	" civilian labour force (in terms of man-hour).
$\bar{u}$	" unemployment ratio.
ω	" average wage and salary per employee (at current prices).
$\bar{i}$	" average interest rate on loan.
$\bar{\rho}$	" foreign exchange rate (in terms of SDR).
b	" basic balance of payment.
$\bar{j}$	" balance of the capital accounts.
p_y	" labor productivity index.
$\bar{t}_m$	" rate of customs duty to total imports.
p	" implicit deflater of GDP.
p_c	" implicit deflater of private consumption expenditure (consumers prices index).
p_{cg}	" implicit deflater of government consumption.
p_i	" implicit deflater of fixed equipment investment.
p_h	" implicit deflater of housing investment.
p_w	" implicit deflater of increase in stocks (wholesale prices index).
p_e	" export price index.
p_m	" import price index.
o_{da}	" each DAC country's total official development assistance (net).
i_v	" money supply-real income income index.

$o_{da(i,j)}$	An element of $o_{da(i,j)}$ matrix which denotes official development assistance from DAC country i to LDC country j.
Δs_{op}	A column vector of n element which denotes each DAC country's overseas private investment (net) to LDC countries.
s_{op}	" overseas private investment balance.
$\Delta s_{op(i,j)}$	An element of $\Delta s_{op(i,j)}$ matrix which denotes overseas private investment from DAC country i to LDC country j.
$\bar{a}_m$	A column vector of n element which denotes each LDC's official development assistance (net) received from multilateral agencies.
$\bar{a}_c$	" each LDC's official development assistance (net) received from centrally planned economy zone.
m_s	" money supply.
$\bar{r}^*_{dm}$	" imports of technology.
$\hat{p}_{eo}$	A scalar of export price index of the rest of the world.
$\hat{p}_{mo}$	" import price index of the rest of the world.
$\hat{p}_{eE}$	" oil export unit price index.
$\hat{i}_{qw}$	" international liquidity index (world total).
$\hat{T}^*_o$	" world imports excluding n countries in the endogenous region.
$\hat{p}_{ec}$	" export price index of primary commodities.
t	Denotes time.
-	Denotes the exogenous variables of the model.
$\bar{z}$	Denotes dummy variables.
A	A n x n matrix which denotes the constants of export functions from country i to country j within endogenous region.
B, Γ, Ξ	A n x n matrix which denotes the coefficients of export functions from country i to country j within endogenous region.
α	A column vector of n element which denotes the constants of a group of structural equations.
β, γ, δ, θ, λ, π, ε, φ, μ, Ψ	A diagonal matrix of a n x n order which denotes coefficients of a group of structural equations.
$\bar{\Pi}$, $\bar{\Theta}$, $\bar{\Omega}$, $\bar{K}$	Development assistance policy parameters.

APPENDIX 3

Estimation of the Model's Structural Parameters

In estimating the macro-model's structural parameters, the main statistical data used were as follows:

United Nations,	Yearbook of National Accounts Statistics
	Statistical Yearbook for Asia and the Far East
	Demographic Yearbook
	Monthly Bulletin of Statistics
OECD,	National Accounts of OECD Countries
	Labour Force Statistics
	Development Co-operation
ILO,	Yerabook of Labour Statistics
IMF,	Direction of Trade
	International Financial Statistics

The above were supplemented by studies by the World Bank and by statistics published by the governments and central banks of the nations concerned.

In order to adjust these basic statistics into units of calculation applicable in common to all the various countries, as required by the multi-nation model, national income and other statistics are given a reference base in terms of constant prices uniformly set to conform to 1970 levels. Units of currency in each country are tranposed into units of "millions of US dollars." Indexes for prices and the like are uniformly set with reference to 1970 levels. Statistics on population and number of employed persons are expressed in units of "thousands of persons."

Time series data needed for estimating the model's structural parameters were insofar as possible collected for the 20-year period from 1954 through 1973. Even in the case of developing countries, most of in which data was incomplete, information was compiled for, at the very least, the 12-year period from 1960 through 1971.

On the basis of the above data, an estimation is made of those parameters to be used in designating the variables which in turn determine the specific system structure which our multi-nation model will assume for purposes of examining a given problem. The total system used in the multi-nation model has been referred to already, but it remains to be pointed out that a special characteristic of the model is that the many variables and paramaters making up the model's system structure can themselves be changed with each change or addition of data. In the usual econometric model, the structural parameters assigned to given variables may change with a change or addition of data, but the set of variables which determine the system structure itself cannot be easily changed. However, the multi-nation model is designed so as to permit quick and flexible changes in the combination of variables used for purposes of responding to new information and data.

Indeed, one reason for developing the multi-nation model is the fact that since the "systems structures" of various countries are not necessarily alike, for purposes of responding appropriately to these variatious among countries the use of any inflexible sort of system structure in an economic model will involve difficulties.

Let us now refer to some concrete procedures. Firstly, we must designate a specific set of structural equations using some or all of the full complement of explanatory variables permitted by the various possible types of structural equations which may be used in the model. Since there may be differences in system structure dependent upon the country or time period under consideration, it is not necessarily the case that a given set of explanatory variables will be uniformly applicable throughout the entire model. Thus the setting up of a specific program is done through a process of discarding those explanetory variables considered to have low statistical reliability, and then making repeated trial calculations with respect to a uniformly applied set of equations until the most appropriate combination of variables is achieved. In this way the multi-nation model, capable of reflecting subtle differences in the systems structures of each country, takes concrete form. Of course, if the constituent data are changed or ammended, the specific set of equations used may be respecified with the result that the model's system structure itself will change, in keeping with the model's special merit of being able to respond to dynamic changes in the real-world environment.

Discussion

When asked to clarify the notion of "arable land", Kaya replied that it is not potential arable land, but rather cultivated land that is considered in his model. The growth rates referred to are calculated for a five-year period; they are overall growth rates and not the average annual growth rates.

Etienne advised that official FAO figures for fertilizer are not comparable among countries since they refer to different bases. Kaya agreed to check these figures carefully.

Waelbroeck suggested that in a model of this size one should differentiate more sharply between developing and developed countries. Not in all countries will export function be equally dependent on domestic wages. Exports also depend on prime rate commodity prices; for developing nations, the availability of foreign currency may be a strong determining factor. In reply, Onishi explained that they made great efforts to determine what function to use.

As regards fertilizers, Etienne pointed out that it might be misleading to use average national figures. In India, for instance, there are large areas that do not use any fertilizers. If, however, the country was treated as a whole, the increase in fertilizer in some parts would be attributed erroneously to the entire country.

A CONCEPTUAL OVERVIEW OF AGRICULTURAL MODELS

Donella H. Meadows

The Dartmouth System Dynamics Group is currently engaged in a survey of models of agricultural development in industrializing countries. The survey has three objectives:

1. To illustrate how complex models based on dissimilar methodologies can be analyzed within a common format and communicated so that a non-technical audience can compare and evaluate them.

2. To summarize the insights these models can contribute to a difficult current socio-economic problem.

3. To suggest how the process of modeling, the interaction with policy makers, and the reporting of results might be better structured to emphasize the inherent strengths of computer models and to allow policy makers to make informed choices among the many problem-solving methods now available to them.

The seven models currently included in our study, their sponsors, countries of application, and modeling approaches, are summarized in Table I.

Table I

Agricultural Models Included in the Study

Model Name or Author	Sponsoring Institution	Modeling Institution	Region of Application	Methods Employed
BACHUE II	ILO	ILO	Philippines & others	input-output, dynamic simulation
Gupta	IBRD	IBRD	Argentina	econometrics
KASM	AID	Michigan State	Korea	input-output, linear programming dynamic simulation
LTSM	FAO	FAO	Egypt & others	dynamic simulation
Picardi	AID	MIT	Sahel	system dynamics
TEMPO	AID	GE	Guatemala, Turkey & others	dynamic simulation
Thomas	Ford,IBRD	Harvard	Bangladesh	hierarchical, linear programming

We have assembled and reviewed the available documentation on these models and in several cases directly interviewed the project teams concerning unclear points or unfinished work. Each model is being assessed according to a checklist as follows:

1. Purpose: Who is the sponsor and what does he hope to gain by having a model made? What is the modeler's purpose (if different from that of the sponsor)? To what real-world problems is the model addressed? What policies are to be tested, or what information is to be generated?

2. Time horizon: Over what period of time does the modeler attempt to describe the system's behavior? Is this period consistent with the model's prupose?

3. Boundary diagram: What variables have been included in the model? Which are affected by system behavior (endogenous) and which are independent of system behavior (exogenous)? Are the reasons for variable inclusion/exclusion made clear? Are the included variables consistent with the purpose and time horizon?

4. Causal-correlative structure: What form does the network of variable interaction take? How does each variable tie into the system? Are relationships described in detail, or are they presented in highly aggregated forms?

5. Method: What mathematical techniques have been used in formalizing the system? Are relationships generally made linear? Are analytic solutions sought? Are random variables an important part of model behavior? Does the model extrapolate the future from past data, or does it attempt to find ways to guide the system toward a stated norm? What is the inherent accuracy of the computation, compared to the accuracy required by #1? What limitations are imposed on the model behavior by the techniques used?

6. Data sources and handling: Are the sources of data made clear? How have crude data been refined to meet the model's data requirements? How have "soft" variables such as attitudes been handled? What has been done where needed data were not available?

7. Equations: Where are equations available? Are they explained? Is it possible for the program to be implemented on another computer system?

8. Validity/sensitivity: How has the functioning of the model been tested? What criteria were used to judge model validity? How does the model respond to changes in data input? Is its behavior dependent on poorly substantiated structure or parameters?

9. Conclusions and recommendations: What is concluded about the system described by the model? What policies are recommended?

10. Implementation history: Have the modelers' efforts been useful in formulating policy? Who, if anyone, has used the model? What successes and what problems have been encountered by people using the model?

11. Hardware requirements: What is the program's run-time? How much storage space does it require? How much core does it require? For what computer system was it designed? What computer language is it written in?

12. Evaluation criteria: Does the modeler provide guidelines for evaluating his work? Does he present it in such a way as to help users improve the model as they use it?

13. Documentation grade: How well does the model documentation allow the above checkpoints to be assessed? Is the writing clear, organized, informative?

14. References: Where can documentation be found? Which published documents are most directly helpful in summarizing the important characteristics of the model?

In attempting to answer these questions for all the models in the study, we have encountered two significant difficulties. The first is the problem of documentation. Although a number of the models are described in several volumes, or as many as 50 published papers, their documentation rarely permits most of the questions on the checklist to be answered without either hours of searching or a conversation with the modeling team. The items least clearly documented tend to be purpose, structure, validity/sensitivity, implementation history, and evaluation criteria.

The second difficulty in such a model comparison is the representation of basic assumptions, or structure, in a common format that can allow rapid understanding of the content, omissions, similarities, and differences of the models. We have adopted three different ways of illustrating the structure of the models; verbal listing of major assumptions, causal-loop diagramming, and comparison with a reference structure. Each of these structural representation techniques will be demonstrated here, using the agriculture sector of WORLD3[1] as an example.

1. Verbal Listing of Major Assumptions

Persons who are not involved in the physical sciences or in computer modeling are accustomed to communicating in words. Thus a verbal summary of model structure is essential, if the model is to be communicated to policy makers and the general public. Such a summary is often very difficult to write; it must capture all important explicit model assumptions, to allow meaningful evaluation, discussion, and criticism. Unimportant details should be omitted so that the focus is centered only on those factors that actually determine the behavior of the model and the conclusions drawn from it. Technical jargon should be avoided.

Our attempt to summarize the basic structure of the WORLD3 agriculture sector resulted in the following list:

1. Food is produced from arable land and agricultural inputs (fertilizer, seed, pesticides).
2. Food output increases when the arable land area, the land fertility, or the amount of agricultural inputs are increased.
3. There are decreasing marginal returns to the use of agricultural inputs.

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[1] D.L. Meadows, et.al., The Dynamics of Growth in a Finite World, Cambridge, Mass., Wright-Allen Press, 1974

4. The amount of potentially arable land is finite, and development costs per hectare (for clearing, roads, irrigation dams) increase as the stock of potentially arable land decreases; in other words, the best and most accessible land is used first.

5. Newly developed land enters at the current average land fertility.

6. Arable land erodes irreversibly on a time scale of centuries when subject to intense cultivation, unless countermeasures are taken.

7. The stock of arable land is decreased by urban-industrial building activity, the rate of decrease depending on both population and industrial growth.

8. Total investment in agriculture increases in the long run with increasing industrial output per capita and in the short run when forced to do so by food shortages.

9. Agricultural investment can be used to develop new land or to increase the amount of agricultural inputs on present land. Investment is allocated on the basis of the relative marginal productivities of the options measured in vegetable-equivalent kilograms per dollar-year.

10. The capital-intensive use of land can lead to persistent pollution of the land (high pesticide concentrations, salinity, heavy-metal poisoning).

11. Land fertility decreases on a time scale of decades when the level of persistent pollutants becomes high.

12. Land fertility regenerates itself over decades, and the process can be speeded up by proper land maintenance.

13. Farmers tend to maintain soil fertility by the proper use of capital except when pressured by extreme food shortages.

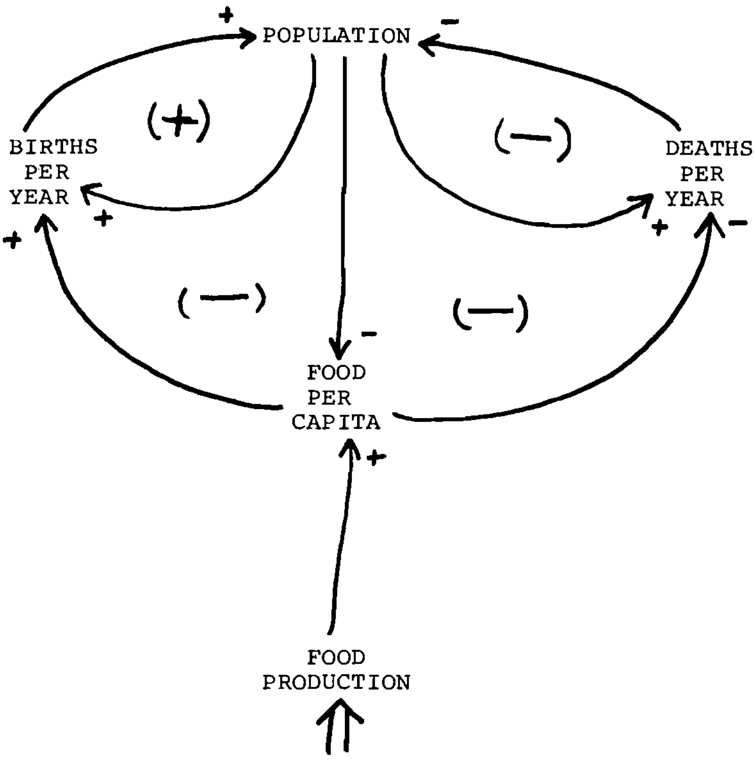
14. Land yield is reduced by air pollution.

2. Causal-loop Diagram

A linear verbal list of assumptions may be easy for a nontechnical audience to understand, but it fails to represent an important feature of many systems-analysis techniques: the assumptions are interlinked in a simultaneous, dynamic, feedback arrangement of mutual interaction. There is no simple way to communicate feedback structure to an untrained audience; instead we have sought a technique that involves minimal necessary training. We find that causal diagramming can be taught within less than one hour, and can be used by people who are not professional modelers, both to discuss existing models and to formulate new ones.

A causal diagram consists of words to represent important model elements and arrows to indicate relationships between the elements. For example, a very simple population model is represented causally in Figure 1. The arrow from births per year to population indicates that the first element causes changes in the second. The arrow is positive (+), indicating that an increase in births per year causes an increase in population. Another positive arrow completes the feedback; as population increases, births per year also increase, all else equal. This closed chain of two positive relationships form a positive feedback loop, represented by a + sign within parenthesis in the middle of the loop. A negative feedback loop links population, food per capita, and deaths. As population increases (all else equal), food per capita decreases. As food per capita decreases, deaths per year increase. As deaths increase, population decreases. In this simple model food production is considered exogenous, as indicated by the double arrow (⇑).

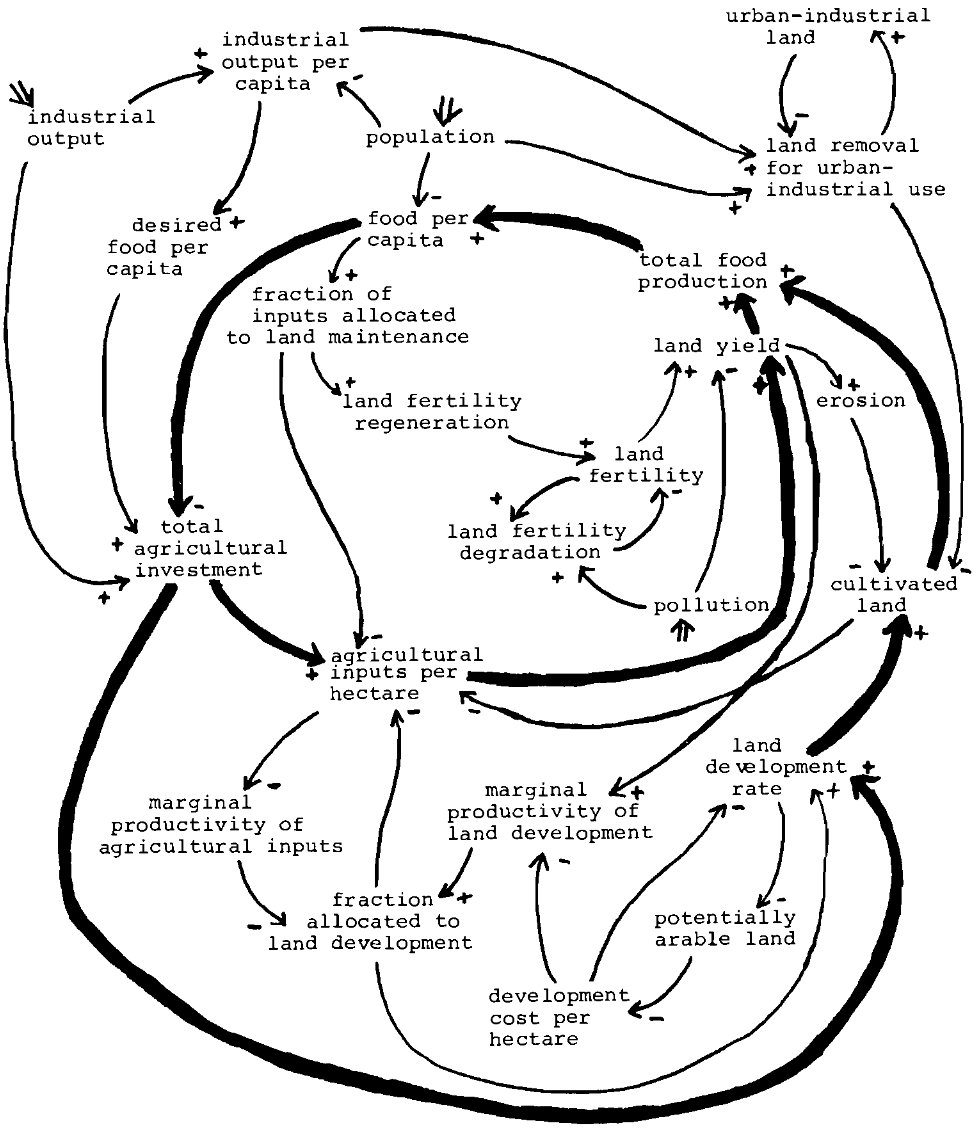
Figure 1
Simple Causal-Loop Diagram



Causal diagrams can illustrate at a glance the configurations of relationships that constitute the basic frameworks of a series of models. Some agricultural models may assume population is exogenous, some may include a feedback from food to population, some may include a positive feedback from population to labor force to food output back to population. All these differences are easily represented in causal-loop form. On the other hand, the quantitative nature of each relationship is not pictured. In order to determine whether the relationship represented by each arrow is strong or weak, linear or nonlinear, instantaneous or delayed, reference must be made to the model equations. The causal diagram is only designed to sketch the qualitative structure of the model. It may and should lead to questions about quantitative assumptions, and at that point the discussion moves from structure to parameters.

The causal-loop diagram of the agriculture sector of WORLD3 is shown in Figure 2. In this case the exogenous factors are inputs from other sectors of the world model. The two feedback loops outlined in heavy arrows are particularly important in determining the behavior of the model. They are negative loops that act to regulate food per capita by directing investment to land development or to agricultural inputs (fertilizer, pesticides, etc.), depending on the relative marginal productivities of each option. Numerous minor loops in the model represent contraints to agricultural output through land fertility, erosion, pollution, diminishing returns, and the global limit of potentially arable land.

Figure 2
Causal-loop diagram, agriculture sector of WORLD3



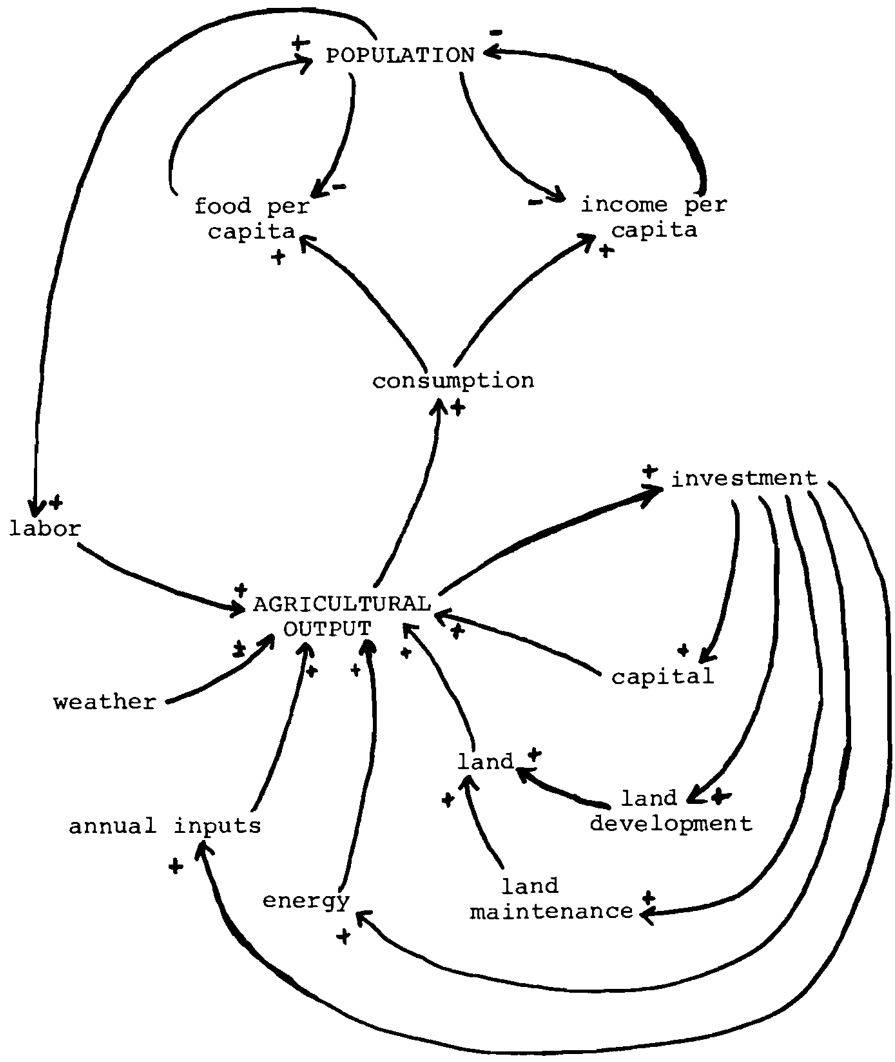
3. Comparison with a Reference Structure

The causal diagram may provide a simple representation of what is contained in a model, but it does not indicate clearly what is omitted. In order to compare the comprehensiveness of models, we have evolved a third way of representing them. By combining the causal diagrams of all the agricultural models in our study, we produced a compendium of all the elements and interrelationships that any modeler had thought important to agricultural systems. Of course there was a great deal of overlap; every model contained an agricultural production function and a measure of agricultural output, for instance. The areas of overlap indicated the most basic, obvious, and important aspects of general agricultural systems. Figure 3 illustrates in causal-loop format the elements and relationships that most often appeared in the models.

Implicit in the arrows of Figure 3 are a number of extremely complex real-world phenomena, which are included in the models in a variety of different mathematical forms. For instance, all the arrows leading from investment to capital, energy, and the other factors of production imply a set of investment allocation decisions that could include optimization, costs, marginal returns, profits, inventories, financing, production delays, and many other considerations. The multiple arrows from the factors of production to agricultural output can be represented by a simple Cobb-Douglas production function, by an input/output matrix, or by a set of ecological and

Figure 3

Most basic elements and relationships in agricultural models



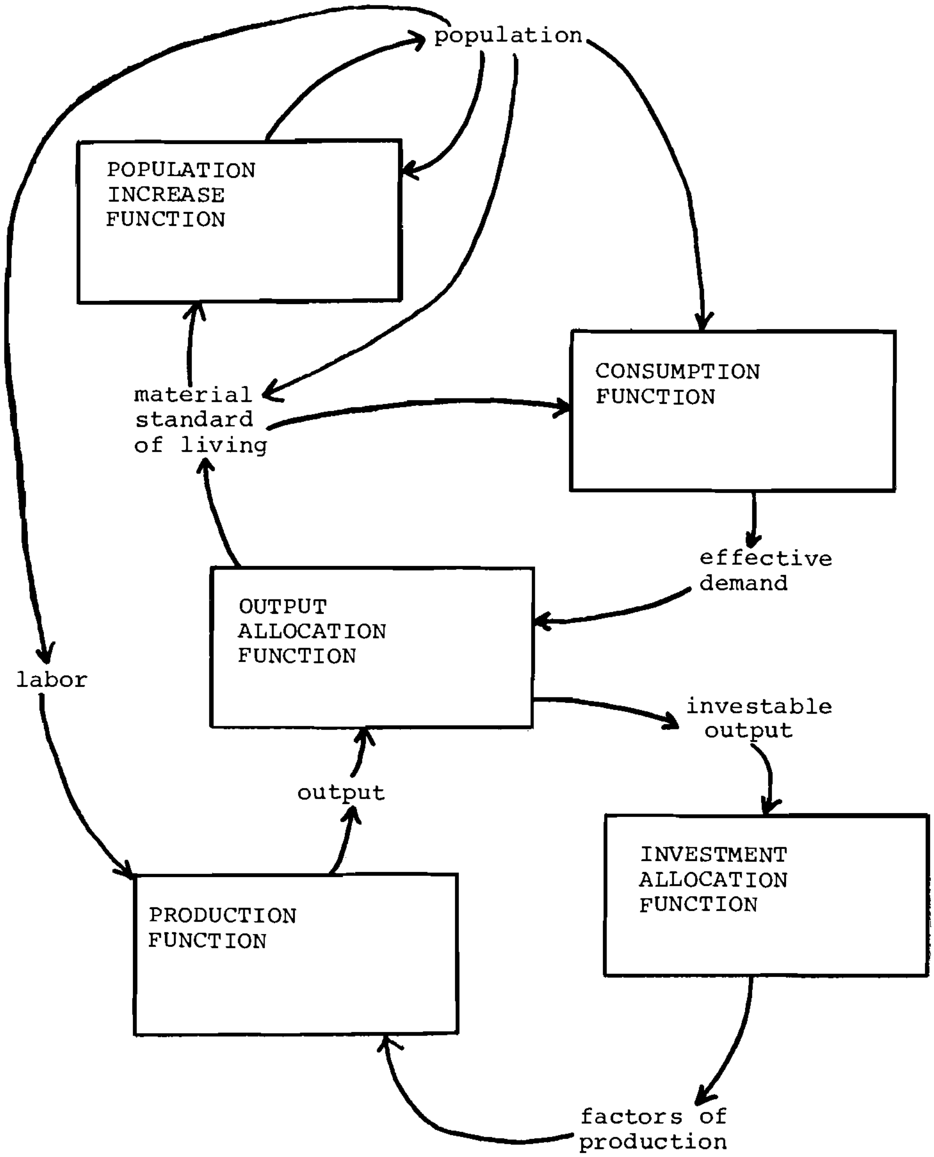
biological relationships. Similar complexities arise in the allocation of output between comsumption and savings, in the representation of the population's consumption habits, and in the influence of food, income, and other factors on the population growth rate.

If Figure 3 is redrawn to emphasize these recurring relationships where social, economic, and physical factors interact to influence human decisions, the diagram in Figure 4 emerges. This is not a causal-loop diagram of the format used in previous figures in this paper. Instead it emphasizes the decision functions in the system, by enclosing them in boxes. Population size and material standard of living are inputs to a set of socioeconomic factors, called a Consumption Function, that determines effective demand. This demand, together with agricultural output (supply), enters an Output Allocation Function that determines how output is divided between current consumption and investment, and also how both consumption and investment are distributed over the population. The actual consumption (material standard of living) and its distribution, combined with demographic factors, influence the population growth rate through a Population Increase Function. Population determines the size of the labor force, which enters the Production Function, along with all the non-human factors of production.

Figure 4 represents the most basic elements of a strictly agricultural model, but several of the models we investigated did not restrict themselves to agriculture alone. They recognized

Figure 4

Basic elements redrawn to emphasize decision functions



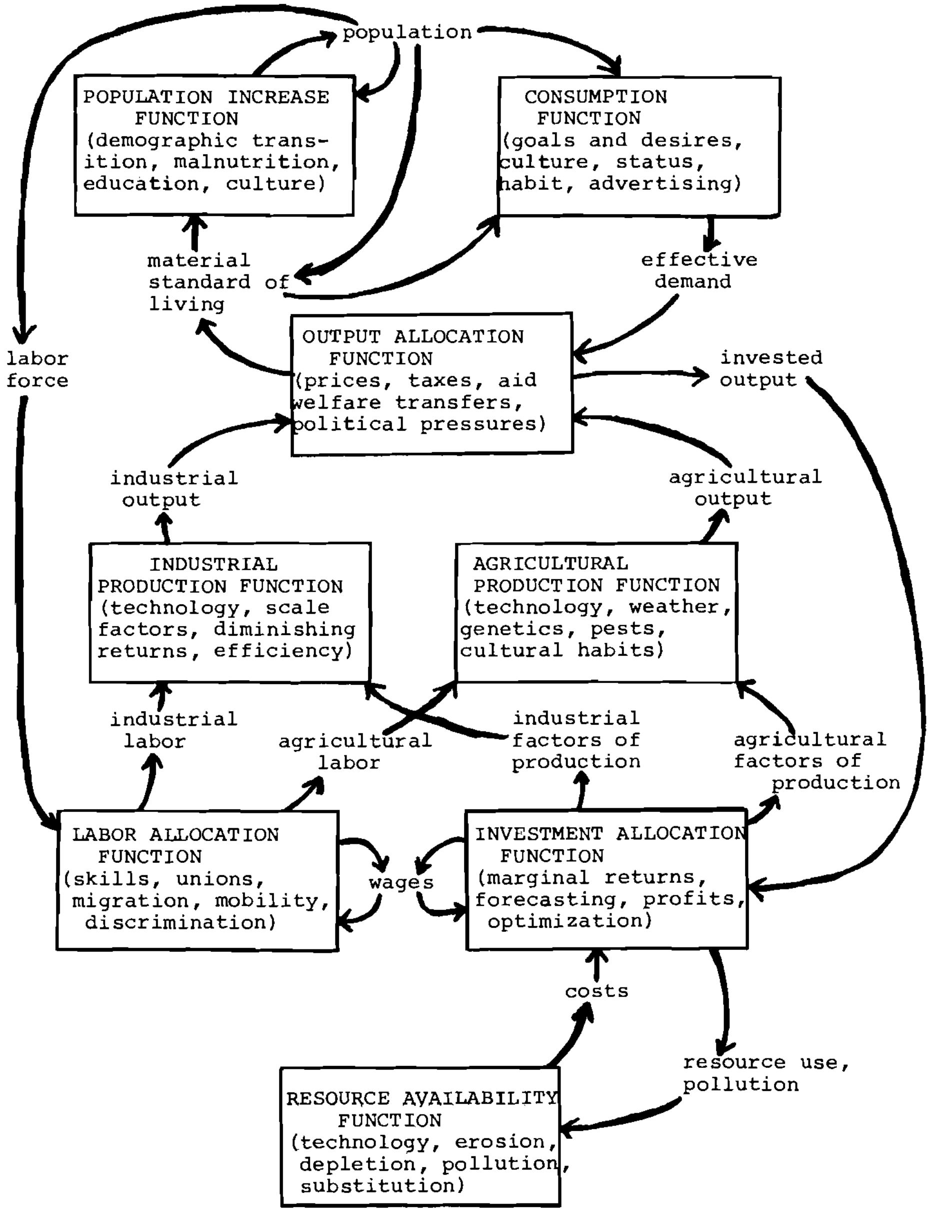
important interactions with the industrial sector, both in competition for labor and resources, and in the improvements of agricultural inputs and capital that come from a developed industrial economy. A two-sector expansion of Figure 4 is shown in Figure 5. A Labor Allocation Function has been added to distribute labor between industry and agriculture, an Industrial Production Function supplements the agricultural one, and a Resource Availability Function represents the costs of various factors of production.

We intend to use the structure represented in Figure 5 as a reference structure, to which the actual structures of the models under study will be compared. We postulate that the relationships and decision functions shown in Figure 5 actually exist in every real economic system. Thus any model can be characterized by

1. which relationships and decision functions it includes and omits, and
2. how it represents the basic decision functions .

Although the use of a reference structure is a test of model comprehensiveness, we do not mean to imply that a more comprehensive model is necessarily "better" than one that omits part of the reference structure. Models are necessary in the first place because the real world is too complex to understand in all its detail. Models must be simplifications. Any model that contained all the relationships in Figure 5 and represented all the decision functions in complete detail would be incomprehensible, and useless, except as a black box (and if one must use a black box, the real world will serve as well as a model).

Figure 5
Reference Structure



Since every model must omit and simplify, the omissions and simplifications of each model must be judged in the light of the model's purpose. A model intended for precise prediction of a few closely-linked variables over a short time horizon may focus on one decision function from Figure 5 in great detail, while treating the rest of the system as exogenous. On the other hand, a long-term model designed to explore qualitative trends may include nearly everything in the system, but represent none of it in detail.

WORLD3 was intended as a broad, shallow model, rather than a narrow, deep one. Its purpose was to explore the basic, long-term behavioral tendencies of the global population/economic system. Therefore one would expect it to contain most of the reference structure, and, as Figure 6 indicates, it does. The labor sector was omitted, on the assumption that over the time horizon of the model (1900-2100) labor would not be a limiting factor in production. The treatment of the various decision functions is indicated briefly in the boxes; a more complete outline follows:

<u>Population Increase Function</u>

population change = births-deaths (no migration)

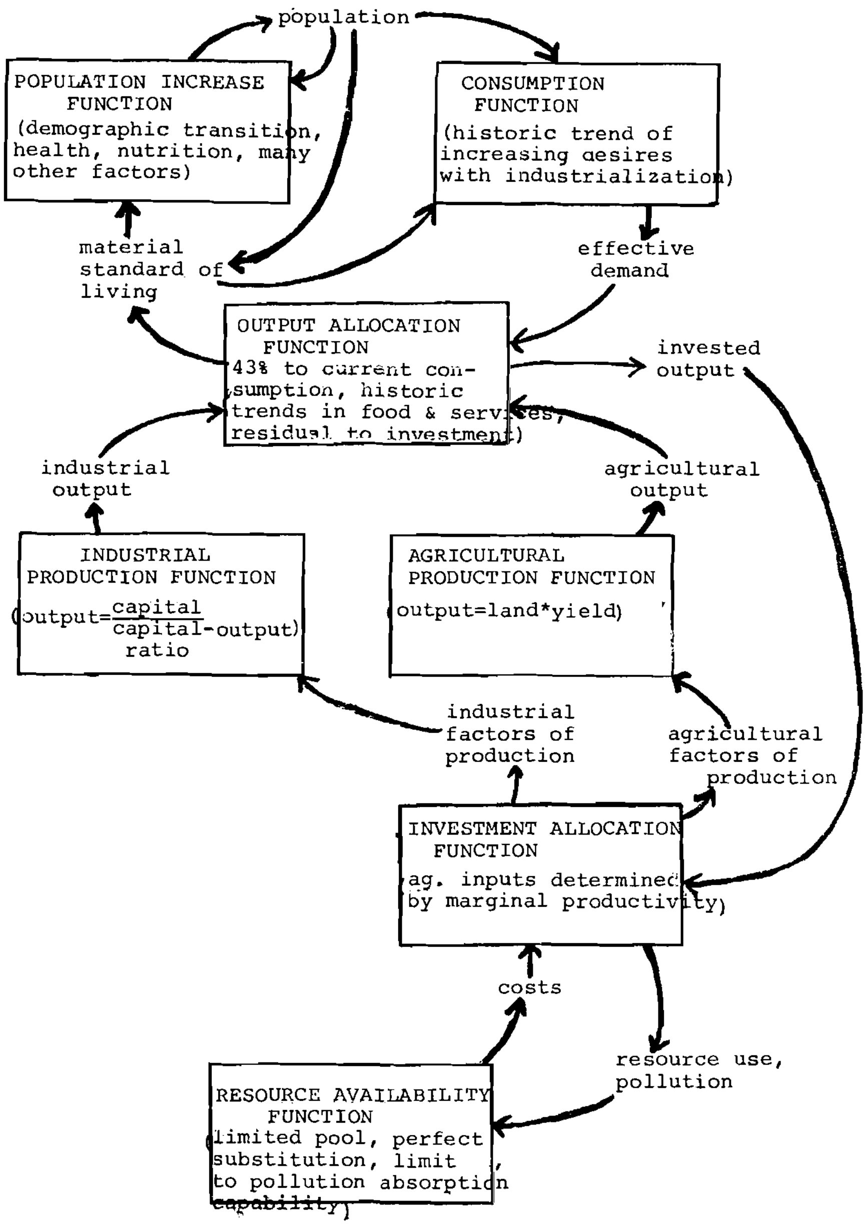
births influenced by age structure, health, family planning,
compensation for infant mortality,
demographic transition (long term)
economic booms and recessions (short term)

deaths influenced by food per capita
health services per capita
pollution
crowding

(All relationships are nonlinear, most are delayed)

Figure 6

Comparison of WORLD3 with reference structure



Consumption Function

Desire for food,services, industrial goods determined by industrial output per capita according to historic trend. Industrialization causes shift in emphasis from food to industry to services. All desires are saturable.

Output Allocation Function

Constant 43% to military and nondurable consumer goods

Allocation to food and services depends nonlinearly on gap between desired and actual levels.

Residual is allocated to investment

No treatment of distribution equity---all goods assumed distributed according to current worldwide patterns

Industrial Production Function

$$\text{output} = \frac{\text{capital}}{\text{capital-output ratio}} * \left(1 - \begin{array}{c}\text{fraction of} \\ \text{capital allocated} \\ \text{to obtaining} \\ \text{resources}\end{array}\right)$$

Capital-output ratio constant---no diminishing returns

Capital = integration of past investments and depreciation

Fraction of capital allocated to obtaining resources represents higher costs with increasing depletion

Agricultural Production Function

output = land* land yield

land increased by development, decreased by erosion and urban-industrial expansion

land yield determined by inherent soil fertility, pollution, agricultural inputs (with diminishing returns)

Labor Allocation Function

omitted

Investment Allocation Function

Capital and resources are only factors of production on industrial side---resources for current operation are given priority over capital expansion

Decision between current inputs and land development on agricultural side determined by relative marginal productivities.

Sufficient allocation to land maintenance, except under severe food shortage

Resource Availability Function

Nonrenewable resources---undifferentiated pool, perfect substitution, cost goes up nonlinearly as pool depleted

Land---limited stock of potentially arable land, cost of development increases as stock depleted

Pollution absorption---maximum rate of natural pollution absorption, pollution itself interferes with the absorption mechanisms.

In applying these three structural representation techniques---verbal listing of major assumptions, causal-loop diagramming, and comparison with a reference structure---to our own model and to others, we have concluded that each reveals something important about the model, none is sufficient in itself, and all three together provide a useful summary of a model's primary assumptions. All three can be understood by a policy-maker with no special technical training. We believe that a major advantage of computer models over mental models is that they are precise and explicit and accessible for evaluation and criticism. In order for that advantage to be realized and for decision-makers to be able to select the most useful models for their purposes, the models must be expressed in terms they can understand. It is up to us, the modelers, to make our models understandable.

Discussion

Cole stressed the importance of the Meadows paper, adding that one should not only assess a particular "decision maker", but also analyze how the information is being used and try to understand how it is being assimilated in the socio-political process. There is a vociferous debate taking place as to what extent political considerations are compatible with scientific method.

It is important to understand the relationship between the scientific method involved and the political considerations. Part of the study should therefore be devoted to an assessment of how this relationship can be improved.

Spharim stressed the importance of including,in an investment function, the resources allocated to agricultural research. In the future, this may prove to be of much greater relevance than many other factors. Parikh, following the line of reasoning of Cole, stressed that, when trying to implement his findings, the modeler often conflicts with vested interests. It is an open question as to what extent the modeler himself should indulge in lobbying, organizing, advertising, and stimulating public opinion.

In reply to several questions, Meadows repeated that a model should not be considered a better model simply because it covers more aspects than another model. The decisive criterion should be to what extent a model includes all that is needed to address its purpose--that is, the phenomenon under investigation. Waelbroeck opined that, in addition to clarifying his thoughts to the policy maker, the model builder should in the future try to take into account more closely the actual decision variables. Kulikowski stressed the need for the modeler to bear in mind who the decision maker is. Situations may appear differently vis-à-vis different decision makers.

Sensitivity Analysis of the Food Model

(Latin American World Model)

Gilberto C. Gallopín

INTRODUCTION

The parameters of global models are affected by errors that are often very difficult or even impossible to estimate. The conclusions and numerical value of the outputs are generally dependent upon the values of the parameters. It is therefore important to ensure that the output of the model does not change drastically with relatively small variations of the parameters; that is, that the model is stable with respect to parameter variation.

A dynamic model can be characterized by the relation

$$Y(t,q) = A[X(t,q)] \qquad (1)$$

where X is an input vector, Y is an output vector, and A is an operator, q is the initial state and parameter vector, and t is time. The system (1) will be considered here as stable if

$$F(t,\Delta q) = \| Y(t,q + \Delta q) - Y(t,q) \| < E \quad \text{for } \| \Delta q \| < \delta \ . \qquad (2)$$

In general for complex, non-linear, dynamic models, the effect of a variation in the values of the parameters will be time-dependent--that is, a given variation will imply a different F at different instances of time. The stability of the output vis-à-vis small variations of the parameters, that is, the preservation of the qualitative picture of the trajectories Y(t), is called *structural stability* [1]. An indication of the structural stability of the system for *individual variations* of the parameters can be represented by

$$\frac{F(t,q,\Delta pi)}{\Delta pi} = \Delta S$$

where q is the initial state and parameter vector, and pi is an individual parameter not in q. Thus

$$F(t,q,\Delta pi) = \| Y(t,q,pi + \Delta pi) - Y(t,q,pi) \| \ .$$

If equation (3) has a limiting value as Δpi approaches zero, we get

$$\lim_{\Delta pi \to o} \frac{F(t,q,\Delta pi)}{\Delta pi} = \frac{dF(t,q,pi)}{d\ pi} = S(t,q,pi) \quad , \tag{4}$$

which is essentially the same as Tomovic's *dynamic sensitivity coefficient* [1].

If the system is in a steady state, then

$$F(t,q,\Delta pi) = F(q,\Delta pi) \text{ and } S(t,q,pi) = S(q,pi) \quad , \tag{5}$$

which is the *static sensitivity coefficient.*

The dynamic sensitivity coefficient generally will depend on the original value of the parameter under consideration (pi), and also on the time and on the values of the other parameters of the system (q). Given that the parameters are usually defined in different units, for the purposes of comparing the sensitivity of the system to different individual parameter variables, we will define a *relative sensitivity coefficient* in the following way:

$$\frac{[Y(t,q,pi+\Delta pi) - Y(t,q,pi)]/Y(t,q,pi)}{\Delta pi/pi} = \Delta SR \quad , \tag{5}$$

where SR is the relative sensitivity of the output to parameter pi, measured in terms of the percent change in the output divided by the percent change in the parameter. In the limit, $\Delta SR = SR(t,q,pi)$. The sensitivity measures defined above indicate the effect of small perturbations in the values of the individual parameters the output which is of the system. The numerical values of the coefficients indicate the parameter that is important in terms of output modification, when varying one parameter at a time. Besides, if the output is relatively insensitive to a particular parameter variation, the exact value of the parameter is not worth determining.

When considering the simultaneous variation of the parameters, the problem changes. In general, the effect of the simultaneous perturbation of the parameters on the output will not be a linear combination of the effects of the individual perturbations. Also, a model insensitive to the perturbation of all parameters, perturbed one at a time, may be very sensitive to a joint combination of perturbations in the parameters. For simulation models, even with small numbers of parameters, calculating the effects of different combinations of perturbations becomes an unmanageable problem, considering the number of combinations and the fact that each evaluation of the output is a complete run of the model. We therefore decided to use the method described by Skolnik and Talavera [2] for maximizing the output perturbation $F(\Delta q)$ at a given time, subject to restrictions in the perturbation in the parameters. (This is essentially a non-linear programming method, derivative free.)

Using this computational method, we are able to identify that combination of parameter perturbations which produces the maximum perturbation in the output, in the neighborhood of the the initial state and parameter vector. If such an output perturbation does not change the results qualitatively, the model can be considered insensitive to parameter variation and the conclusions are robust. If the opposite is the case, it can be concluded that the model is unstable for at least one combination of parameter perturbations.

THE MODEL

The sensitivity analysis was performed upon the food model of the Latin American World Model. (The Sensitivity analysis of the World Model is not feasible, because of the enormous computer time required.) The food model was run separately from the World Model; for the economic input for each year, we used the same sequence of inputs allocated to the food sector in the run of the World Model. This does not imply that the food model with its parameters perturbed would have received exactly the same sequence of inputs from the Whole Model. The latter optimizes for every year the allocation of economic resources to food according to the current state of the economy and to the level of satisfaction of basic needs.

The output criterion used is PERS, the number of persons that could be fed at the assumed per capita level of consumption. The procedure was to obtain the combination of parameter and initial value perturbations which maximize the difference between PERS in the perturbed run and PERS in the standard run for the year 2009, that is, thirty years after the beginning of the run.

The sensitivity was performed for the four blocks of the food model: Developed Countries, Latin America, Africa, and Asia. For the four blocks, the model differs only in the values of the parameters and initial values; this implies that the analysis was performed around four different parameter combinations.

The parameters studied are as follows:

COSTF = unit cost of fertilizer, soil erosion and fertility control, and other agricultural inputs ($\$/10^3$ tons);

PA_1 = agricultural losses in developing countries, final (dimensionless);

PA_0 = agricultural losses, initial (dimensionless);

PG_1 = terrestrial animal production losses in developing countries, final (dimensionless);

PG_o = terrestrial animal production losses, initial (dimensionless);

PP = losses in fishery (dimensionless);

KAC = fraction of arable land allocated to growing major food crops (dimensionless);

REMAX = maximum agricultural yield (10^6 Kcal/ha);

KGK = unit cost of animal production increase ($/Kcal);

TPAS = animal production from potential grazing lands (10^0 Kcal);

KPK = unit cost of fishery production increase ($/Kcal);

EFIC = efficiency of conversion to animal edible carcass (dimensionless);

PESMAX = maximal annual fishery production (Kcal);

CAPE = annual caloric consumption per capita (Kcal/persons/year);

TC_o = arable land, initial (10^3 ha);

FEP_o = fertilizer production, initial (10^3 tons);

$GANAK_o$ = animal production, initial (Kcal);

$PESK_o$ = fishery production, initial (Kcal);

$TPCU_o$ = potentially arable land, initial (10^3 ha);

URBT = urbanization rate, total (ha/year). Here, it was introduced as a constant value.

The output criterion is:

PERS = number of persons that could be fed at the assumed CAPE in the year 2009 (10^6 persons/year)

RESULTS

The values of the parameters and the initial state of these variables whose effects were studied appear in Table 1 for the four blocks of the model. Two kinds of analysis were performed: sensitivity to individual parameter variation, and sensitivity to joint parameter variation.

Table 1. Standard values of the parameters and initial state of the variables in 1980, and the value of the output (PERS in 2009) in the standard run.

Parameter	Developed Countries	Latin America	Africa	Asia
COSTF	.7692 E6	.7692 E6	.7692 E6	.7692 E6
PA_1	-	.10	.10	.10
PA_o	.10	.30	.30	.30
PG_1	-	.10	.10	.10
PG_o	.10	.30	.30	.30
PP	.17	.17	.17	.17
KAC	.526	.529	.434	.940
REMAX	.10	.10	.10	.15
KGK	.150 E-3	.117 E-3	.126 E-3	.151 E-3
TPAS	.1548 E14	.4926 E13	.5765 E13	.6892 E13
KPK	.300 E-4	.550 E-4	.662 E-4	.4348 E-3
PESMAX	.7598 E14	.1546 E14	.7170 E13	.3041 E14
CAPE	.1095 E7	.1095 E7	.1095 E7	.1095 E7
EFIG	.21	.21	.21	.21
TC_o	.6465 E6	.1214 E6	.2882 E6	.4762 E6
FEP_o	.1333 E6	.1038 E5	.5205 E4	.2890 E5
$GANAK_o$	.4025 E15	.4151 E14	.1788 E14	.9167 E14
$PESK_o$	.3294 E14	.1549 E14	.3955 E13	.1720 E14
$TPCU_o$	.1092 E7	.7358 E6	.7320 E6	.6230 E6
URBT	0	0	0	0
PERS 2009	.3743 E10	.7068 E9	.1104 E10	.5496 E10

Individual Parameter Variation

The individual parameters studied are as follows: COSTF, PA_1, PA_o, PG_1, KAC, REMAX, TC, TPCU and CAPE. The model was run with one parameter perturbed in +5%, +10%, −5% and −10% of the standard value for each of the blocks of the model. The results are given in Table 2.

As can be seen from the table, the effect of a given percent increase is not always the same as the effect of an equivalent decrease, owing to the non-linearities of the model. The effect on the output appears to decrease or to increase monotonously with the magnitude of the disturbance in the parameters. The computational procedure of Skolnik and Talavera [2] was used for studying the individual variables in order to determine whether an intermediate value of the parameters would have a stronger effect than do the values explored in Table 2. For all cases no intermediate value with a stronger effect was detected.

The data in Table 2 also show that for CAPE, if the parameters are varied one at a time within the range of ± 10%, the maximum variation in the output is +11% in all blocks, and the variation increases monotonously

Table 2. Effects of individual parameter variation on PERS in the year 2009.

Parameter	Var. %*	Developed Countries		Latin America		Africa		Asia	
		Effect (in %)**	Var/eff.***	Effect (in %)	Var/eff.	Effect (in %)	Var/eff.	Effect (in %)	Var/eff.
COSTF	10	−0.2	−0.02	−0.7	−0.07	−1.1	−0.11	−2.7	−0.27
	5	−0.1	−0.02	−0.4	−0.07	−0.5	−0.11	−1.4	−0.28
	−5	+0.1	+0.02	+0.4	+0.08	+0.5	+0.11	+1.5	+0.29
	−10	+0.2	+0.02	+0.8	+0.08	+1.1	+0.11	+2.7	+0.27
CAPE	10	−9.1	−0.95	−9.1	−0.95	−9.1	−0.95	−9.1	−0.95
	5	−4.8	−0.91	−4.8	−0.91	−4.8	−0.91	−4.8	−0.91
	−5	+5.3	+1.05	+5.3	+1.05	+5.3	+1.05	+5.3	+1.05
	−10	+11.1	+1.11	+11.1	+1.11	+11.1	+1.11	+11.1	+1.11
PA_1	10	-	-	−1.0	−0.10	−1.1	−0.11	−1.1	−0.11
	5	-	-	−0.5	−0.10	−0.5	−0.11	−0.5	−0.11
	−5	-	-	+0.5	+0.10	+0.5	+0.10	+0.5	+0.11
	−10	-	-	+1.0	+0.10	+1.1	+0.11	+1.1	+0.11
PA_o	10	−1.0	−0.10	0	0	0	0	0	0
	5	−0.5	−0.10	0	0	0	0	0	0
	−5	+0.5	+0.10	0	0	0	0	0	0
	−10	+1.0	+0.10	0	0	0	0	0	0
PG_1	10	-	-	−0.1	−0.01	0	0	−0.02	−0.002
	5	-	-	−0.03	−0.01	0	0	0	0
	−5	-	-	+0.03	+0.01	0	0	0	0
	−10	-	-	+0.1	+0.01	0	0	+0.02	+0.002
KAC	10	+9.0	+0.90	+9.4	+0.94	+9.9	+0.99	+9.8	+0.98
	5	+4.5	+0.90	+4.7	+0.94	+5.0	+1.00	+4.9	+0.98
	−5	−4.5	−0.91	−4.7	−0.93	−5.0	−0.98	−4.9	−0.98
	−10	−9.1	−0.91	−9.4	−0.94	−9.9	−0.98	−9.8	−0.98
REMAX	10	+6.4	+0.64	+6.5	+0.65	+6.8	+0.68	0	0
	5	+3.3	+0.66	+3.3	+0.67	+3.5	+0.71	0	0
	−5	−3.5	−0.70	−3.5	−0.70	−3.7	−0.74	−1.0	−0.20
	−10	−7.3	−0.73	−7.2	−0.72	−7.6	−0.76	−3.3	−0.33
TC_o	10	+6.1	+0.61	+6.6	+0.66	+8.2	+0.82	+6.4	+0.64
	5	+3.1	+0.61	+3.3	+0.66	+4.2	+0.83	+3.3	+0.65
	−5	−3.1	−0.63	−3.3	−0.66	−4.1	−0.82	−3.3	−0.67
	−10	−6.3	−0.63	−6.6	−0.66	−8.2	−0.82	−7.0	−0.70
$TPCU_o$	10	+0.3	+0.03	0	0	0	0	0	0
	5	+0.2	+0.08	0	0	0	0	0	0
	−5	−0.3	−0.06	0	0	0	0	0	0
	−10	−0.8	−0.08	0	0	0	0	0	0

*Var. percent is percent variation in the parameter;

**effect percent is percent difference in PERS 2009 with respect to original value;

***Var/effect is the relative sensitivity coefficient.

with the perturbation. It can be concluded that the model is stable with respect to individual variations of the parameters in the neighborhood of the standard values.

The parameters are ranked in Table 3 according to the maximum effect their perturbation produced on the output for the four blocks. The sensitivities were calculated for one instant of time, namely, the year 2009, and they need not be (indeed they probably are not) similar to the sensitivities calculated with reference to other years. For instance, the model's sensitivity to changes in the initial value of $TPCU_o$ will be very high once land becomes a limiting factor (which could be the case after the year 2009). The interval of 30 years from 1980 to 2009 seems a reasonable horizon for medium-term analysis. Nevertheless, the discussion about the factors should take into consideration the above caution.

Table 3. Order of importance of the parameters for output modification and their maximum relative sensitivity (RS).

Rank	Developed Countries		Latin America		Africa		Asia	
	Parameter	RS	Parameter	RS	Parameter	RS	Parameter	RS
1	CAPE	1.11	CAPE	1.11	CAPE	1.11	CAPE	1.11
2	KAC	0.91	KAC	0.94	KAC	0.99	KAC	0.98
3	REMAX	0.73	REMAX	0.72	TC_o	0.82	TC_o	0.70
4	TC_o	0.63	TC_o	0.66	REMAX	0.76	REMAX	0.33
5	PA_o	0.10	PA1	0.10	COSTF PA1	0.11	COSTF	0.29
6	$TPCU_o$	0.08	COSTF	0.08	PA_o, PG_1 $TPCU_o$	0	PA_1	0.11
7	COSTF	0.02	PG1	0.01			PG_1	0.002
8			PAo, TPCUo	0			$TPCU_o$, PA_o	0

The most important single parameter in the model for all blocks is CAPE. While this is clearly not a controllable factor, it shows that a good estimate of caloric requirement is important for the model. The second important factor for all blocks is KAC. With the exception of Asia, all blocks use only about one half of their arable land for producing major food crops, and this parameter is not varied in the model. An immediate mechanism for increasing food production is therefore to increase the KAC. This should be particularly feasible in Africa.

The next factors in order of importance are TC_o, and REMAX. Here, a difference among blocks is evident: REMAX is more important than TC_o for the developed countries and for Latin America, while the inverse is true for Africa and Asia. The relative sensitivity with respect to REMAX is about the same for the Developed Countries, Latin America, and Africa (0.73, 0.72, and 0.76, respectively). In the run, the maximal yield is reached at the beginning (i.e., the year 1980) in the Developed Countries, in 1991 in Latin America, and in 2002 in Africa. These three blocks, therefore, reach maximal yield before the end of the run; it is natural then that REMAX affects the output in the year 2009. Asia does not reach maximal yield (here $15 \cdot 10^6$ Kcal/ha) during the run. Thus the output for Asia is not sensitive to an increase in REMAX (see Table 2) but rather to a decrease in REMAX because in the year 2009 the yield in Asia is expected to be 98% of REMAX.

In Developed Countries and in Latin America, TC_o is less important than REMAX probably because both blocks reach REMAX early in the run and thereafter increase the amount of cultivated land (20% in Developed Countries and 25% in Latin America); the internal optimization procedure apparently compensates for the changes in the initial amount of cultivated land. Africa reaches the maximal yield very late, and Asia does not reach it at all during the interval of the run. It therefore seems very reasonable to assume that the effects of TC_o are more important than those of REMAX.

The effects of agricultural losses (PA_o or PA_1) are about the same for all blocks, affecting directly the final output, and producing a $\pm$10% change in the loss coefficient which in turn produces a $\pm$1% change in the remaining fraction (1-PA). The initial value of the losses in developing countries, PA_o, does not affect the output in the year 2009, because these losses diminish in about twenty years, to their final value of PA_1.

COSTF affects the output through a complicated chain: it affects the increment in fertilizer production, which in turn affects the amount of fertilizer available every year and the amount of fertilizer applied per hectare and, through it, the current yield in a non-linear fashion. Besides, the internal optimization for allocation of economic resources to agricultural inputs and land colonization is affected. Therefore, the effects of a change in fertilizer costs depend on whether maximal yield has been attained, the rate of land colonization, etc; the effect of that parameter is very slight in all blocks. In the time horizon considered, the strongest effect may be observed in Asia, which, to reach the higher yield of 15 • 10^6 Kcal/ha, requires about three times the amount of fertilizer per hectare in the other blocks.

PG_1 have a very low impact on the output, probably due to the relative numerical unimportance of animal food when compared with the agricultural production.

Finally, the importance of the initial value of $TPCU_0$ is slight in the Developed Countries, and has no effect on the output at the year 2009 in the other blocks. This is probably due to the fact that in the run Asia does not increase the cultivated land, and Africa only increases it by 6%. In the model, the effect of TPCU may be seen in the change in unit costs of land colonization. Latin America colonizes land, but the cultivated land at the end of the run is only about 21% of the potentially arable land and therefore the effect upon the colonization costs is very small. In Developed Countries, however, about 72% of the potentially arable land is cultivated at the end of the run, and land scarcity starts to affect the costs of colonization.

Joint Parameter Variation

When many parameters are perturbed simultaneously, a sensitivity coefficient can be calculated. But it is better to present the results in terms of the vector of parameter perturbations, with the values of the particular perturbation in each parameter and the resulting output perturbation.

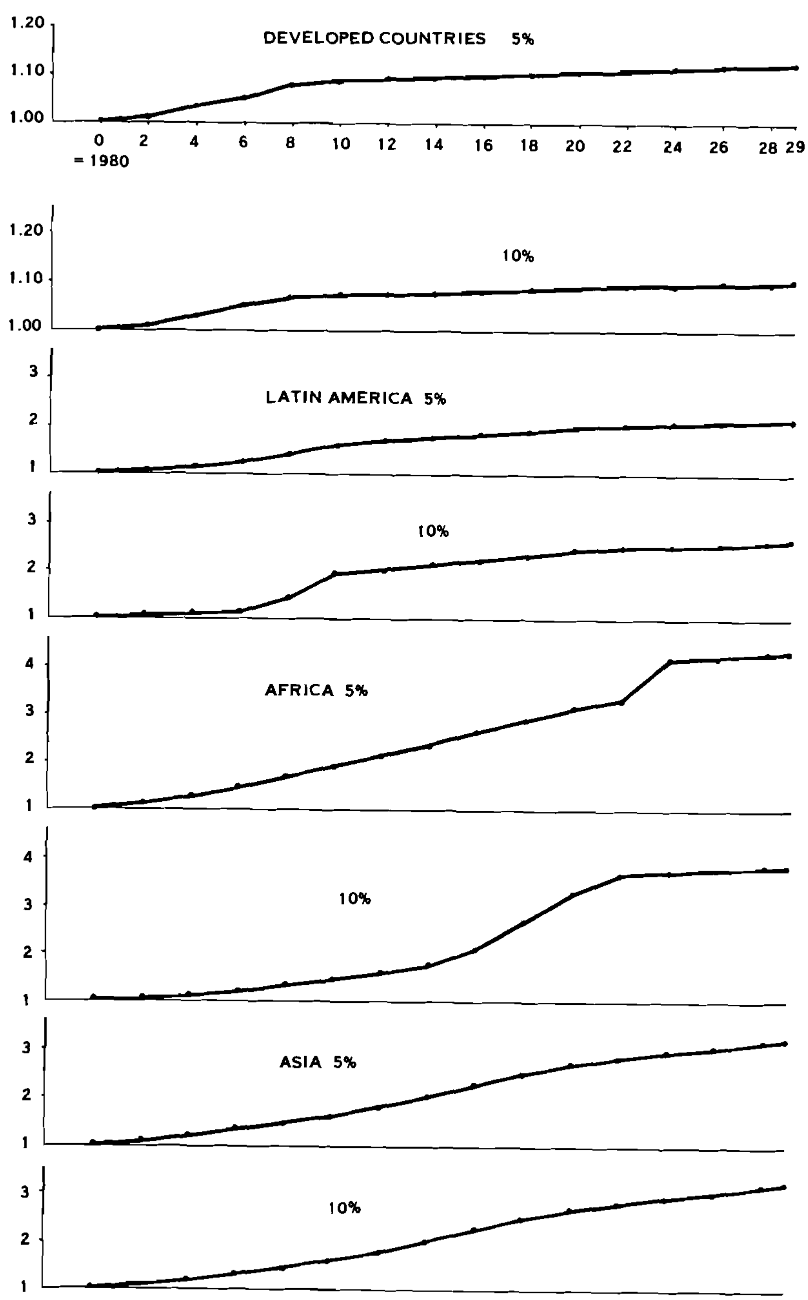
An optimization was used to identify the combination of parameter perturbations, within given limits, which produces the "worst" perturbation in the output. The analysis was performed for the four blocks, allowing a perturbation with ±5% and ±10% of the original values of the parameters. The results appear in Table 4. The maximum perturbation in the output for the "worst" combination of perturbations within the range of ±10% in the parameters is 35.6% in Asia. Considering that individual parameter variation can produce an effect as high as 11.1%, the global effect is not very high. Comparing the values of the effect for the ±5% and the ±10% allowed variation in the parameters, in the latter case, the effect is from 1.48 to 2.69 times the effect with ±5% for different blocks. Figure 1 shows the time behavior of the absolute value of the difference between the outputs of the standard run and the perturbed run, for the four blocks. Note the differences in the scale between Developed Countries and the other three blocks. After a period of rapid increase, the difference tends to reach a constant value. Therefore according to equation (2), the model can be considered quasi stable for the time horizon considered, with no qualitative change in its behavior for the "worst" perturbations considered. Moreover, were the food model connected to the World Model, those perturbations would very likely be counteracted by the optimization mechanisms, by allocation of economic resources.

Table 4. Effects of joint parameter perturbation.

Parameter	Developed Countries		Latin America		Africa		Asia	
	VA*		VA		VA		VA	
	±5%	±10%	±5%	±10%	±5%	±10%	±5%	±10%
COSTF	−5.0	−10.0	−5.0	−10.0	−5.0	−10.0	−5.0	−10.0
PA_1	-	-	−1.2	+10.0	−4.9	+10.0	−2.1	−10.0
PA_o	0	+10.0	0	0	+1.0	0	+1.0	0
PG_1	-	-	−1.2	+10.0	−4.8	+10.0	−2.1	−10.0
PG_o	0	+10.0	0	0	+1.0	0	+1.0	0
PP	0	+9.4	−1.9	+5.9	−4.7	+5.9	−2.2	−5.9
KAC	+1.9	−9.9	+1.9	−7.6	+4.9	−9.2	+4.5	+9.6
REMAX	+0.1	−10.0	+0.1	−10.0	+4.9	−10.0	+1.0	+5.0
KGK	0	0	0	0	+1.0	0	+1.0	0
TPAS	0	0	0	0	+1.0	0	+1.0	0
KPK	0	0	0	0	+1.0	0	+1.0	0
EFIG	0	0	0	0	+1.0	0	+1.0	0
PESMAX	0	0	0	0	+1.0	0	+1.0	0
CAPE	−5.0	+9.9	−5.0	+10.0	−5.0	+10.0	−5.0	−10.0
TC_o	+5.0	−10.0	+5.0	−10.0	+5.0	−10.0	+5.0	+10.0
FEP_o	+5.0	−10.0	+4.9	−10.0	+5.0	−10.0	+5.0	+10.0
$GANAK_o$	0	−10.0	0	−10.0	+1.0	−10.0	+1.0	+10.0
$PESK_o$	0	−10.0	0	−10.0	+1.0	−10.0	+1.0	+10.0
$TPCU_o$	+4.9	−10.0	+5.0	−10.0	+5.0	−10.0	+1.0	0
URBT**	+0.01	+0.05	+0.02	+0.03	+0.003	+0.04	0	0
PERS	+11.3	−30.4	+11.5	−28.0	+20.4	−30.2	+15.7	+35.6

*VA is variation allowed in the parameter values.

**For URBT, the changes indicates the difference between the original (0) value, and the perturbed value.



ORDINATE: Difference between perturbed and standard values of PERS. with the difference at time 0 considered as unity.

Figure 1.

In conclusion, the robustness of the results of the food model against changes in the values of the parameters as high as ±10% has been demonstrated for the year 2009. For this year, the relative importance of individual parameters has been analyzed. The manipulation of the situations represented by the values of the parameters is a possible means for optimizing the food output in each block.

References

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Discussion

Norse stated that in general a great danger for a modeler is that he may obtain a pile of data from FAO, insert them into a program, arrive at some nice correlation coefficient, and derive immediate conclusions therefrom. In particular, he questioned the fertilizer response for Latin America. Niaz added that it is surprising that no other input except fertilizers should have shown positive correlation with the output of food crops; water constraints could play a major role. Weber stressed that the Bariloche model exhibits diminishing returns in applying fertilizers, whereas MOIRA shows a linear dependence. In his opinion, the available data could not prove either of the two points. Gallopin replied that only a portion of all fertilizers is applied to food crops. The Bariloche model may be too pessimistic in the sense that it assumes that the fertilizer is distributed evenly over all crops; this may result in an underestimation of food crops as a function of the application of fertilizers. However, by assuming this, we are on the safe side.

Bernadini asked why no restrictions deriving from unequal income distributions have been introduced. Gallopin replied that, in their scenario, a sufficiently high income redistribution is assumed. In fact, they made a control run, maintaining the present income distribution; the results of this run showed that, even under the most favorable economic conditions, a substantial portion of the population would never be able to reach the defined satisfaction of their basic needs. What they regard as "fertilizer" is merely an indicator of different kinds of inputs to agriculture.

Niaz asked whether this meant that when fertilizer consumption increases, all other inputs would automatically increase proportionally. Gallopin agrees that, to a certain extent, fertilizers can be a proxy for all materials going into agriculture. As to diminishing returns, he believed that there are good theoretical reasons to consider them with respect to fertilizers applied to land; but perhaps not for fertilizers applied to the plant.

Etienne pointed out that this proportionality between fertilizer and other inputs may not always be valid. In a number of Asian countries, the use of pesticides is increasing much more slowly than the use of fertilizers. Furthermore, the mix of fertilizers has to be considered. When discussing the investment capacities of the farmer, one should also consider the concept of minimum economic holding--that is, the holding that the farmer has at the end of a year that enables him to have some cash income for further development. As to physical constraints versus socio-political constraints, Etienne stressed the need to consider both; it is impossible to blame everything on socio-political constraints. In many Middle East countries, and in large parts of Africa, there also exist serious physical constraints.

Brioschi and Weber questioned whether the share of agricultural products fed to animals is sufficiently depicted in the model. Keyzer generalized that there is always a problem where cross-section functions, that have been estimated on a country level, are used on a regional level, in particular where they are nonlinear functions. Gallopin replied that these functions have been estimated over three points in time: for the period

1948 to 1952, for the year 1965, and for the year 1970. Thus it is not a strict cross-section analysis; on the contrary, these estimations suffice to arrive at an estimation of the development over time within particular countries. In reply to Etienne's remark about pesticides, Gallopin stated that this would fall under their model assumption that administrational and socio-political aspects are not constraints; this also applies to the influence of physical limits. While physical constraints may be a problem on a local level, on a regional basis they are assumed to be sufficiently balanced by improved management.

Niaz added that in many countries, such as Pakistan, it has been recognized that land is not a limiting factor; the real limiting factor is water. Gallopin replied that much depends on the level of aggregation considered.

The Problems of Food Production in Certain Asian Countries†

P.C. Roberts and D. Norse

Data inputs eg on land and water resources, and certain functions, such as that for the diminishing marginal response to production inputs, derived for our World Model have been used to build discrete sub-models of food production in India, Bangladesh and Pakistan. The main nutritional deficiency is considered to be food energy, and our models therefore examine food production and consumption in energy terms. These sub-models explore three relationships:

(i) food output and the costs of production
(ii) the fraction of the GDP which goes on food production for domestic consumption, and the mean food energy intake.
(iii) the level of food energy intake and mortality.

In turn, these relationships are exposed to changes in certain exogenous inputs to the system, namely in:

(a) the rate of population increase
(b) the real price of production inputs
(c) the growth rate of the economy (GDP)

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†The views expressed in this paper are those of the authors and do not necessarily coincide with those of the Department of the Environment.

<u>Relationship (i)</u> Land and water resources have been assigned to the appropriate agro-climatic zones, the latter being defined by the level and duration of temperature and rain fall. Irrigated and non-irrigated land generally have different productivities and therefore they are considered separately. Land and water development costs are primarily based on an analysis of agricultural development projects assessed and/or financed by the World Bank and other agencies. Appropriate costs are ascribed to different forms of irrigation, and allowance is made for the rise in costs as greater physical constraints to development are encountered, and also for agricultural and social infrastructure costs in areas not previously settled.

Estimates of the upper asymptote to production, together with input-output data from numerous development projects, have been used to produce curves in Fig 1 for the diminishing marginal response to the package of inputs commonly used for food production. These inputs are largely seed and labour at low output levels, but include fertilizer, pesticides, and machinery at higher production levels. The curves implicitly take into account variation in soil type, cropping pattern and local climate.

The curves in Fig 1 have been used in conjunction with the data on resource stocks and development costs to derive an optimal agricultural development strategy for each of the three countries. Each land resource stock has a 'real' or if undeveloped, a notional diminishing marginal return curve. A computer programme is used, which splits the incremental food energy requirements in any given period into ten equal parts, and scans all the curves to determine the cheapest source of each tenth. Thus optimisation involves choosing at each time step the tranche of land whose productivity can be raised at the lowest cost per unit of food energy output, production being assumed to continue at the current level on all other cultivated land.

When the productivity of this tranche has fallen to that of the next most favourable tranche, which may lie in the same or in a different agro-climatic zone, output is then increased in both tranches, and the remaining tranches of cultivated or cultivable land follow in the same way; thereafter all land is in continuous 'development', but not necessarily at the same rate. The optimal development path thus derived for each country depends on the maintenance of current relative prices of inputs; if anyone input (eg fertilizer) rose in price relative to another, the pattern of development would change. This may be expected to happen, but these simple sub-models lack a relative price change mechanism (however see later comments on the World Model).

Little undeveloped land remains in these 3 countries to be brought into the cultivation cycle, and the development algorithm shows that substantial increases in food production can only be achieved by the increased use of fertilizers and irrigation. Since many of the production inputs depend on depleting natural resources eg fossil fuels for nitrogen fertilizer production, and the pumping of irrigation water, the real price of these inputs is certain to increase. It is not possible to forecast the average rate of change in input prices and therefore the effect of increases of 0, 2 and 5%/yr are examined.

Relationship (ii) Fig 2. Illustrates an apparent relationship between the average energ intake in a country and the proportion of that country's GDP which is devoted to the production of food for domestic consumption. The right hand curve relates to the proportion of the GDP devoted to food prudction and includes some processing and marketing costs, while the left hand curve relates to the GDP fraction devoted to food production at farm gate costs, where the latter exclude management and investment income. Fig 2 suggests that the average calorie consumption decreases progressively as a greater and greater proportion of the GDP has to be allocated to food production. The average intake becomes inadequate when a country is devoting a half or more of its GDP to food production, such that only a small proportion is available for the production of agricultural and/or industrial goods for export.

Relationship (iii) This is drawn between mortality rates, the mean calorie intake and the distribution about this mean. The values of the average calorie intake presented in Fig 2 are not a satisfactory indicator of nutritional standards, because uneven distribution of income, associated with high in-and under-employment may result in a large proportion of the population receiving calorie intakes considerably less than the (national) average. Fig 3 illustrates the uneven calorie consumption across a sample population in Pakistan, together with results from surveys in Tunisia and Brazil. For these three countries the standard deviation ranges from 164-588 kcal./capita/day ie ± 8, 15 and 2 4% of the mean respectively. Given that these values for the standard deviation have been calculated from household survey data, they will under-estimate the extremes of distribution among all individuals of a population.

Although some countries may have a skewed distribution of calorie intake, examination of a range of surveys has shown that at the country or regional level, it is reasonable to assume a normal distribution. Survey result have been plotted, on probability paper to give Fig 4, in which the standard deviation of all of the surveys ie 380 kcal/capita/day is given by the slope of the line. Fig 4 has been used to produce the family of curves in Fig 5, which indicate for a given mean calorie intake, the proportion of the population whose intake lies below a stipulated level. These curves form part of the algorithm which determines the proportinn of the population who are malnourished.

Starvation will occur after a period in which the calorie intake is less than that required to support the basic metabolism under conditions of resting and fasting, or is insufficient to provide maintenance energy if slightly higherlevels of physical activity are considered. The FAO suggest average calorie requirements of c.1100-1200 and c.1700 kcal./capita/day respectively for these two levels of activity in South Asian countries. The survival of a community over a long period of time will require a mean calorie intake exceeding the maintenance level, since food production and preparation are predominantly labour intensive tasks in these regions. However famine commonly occurs as a result of crop failure, and therefore there is little manual work to be done, so that calorie intakes close to the maintenance level may be adequate for survival in the short term.

Various village and regional surveys indicate that communities can survive for long periods at average calorie intake levels much below the minimum of 1,700 proposed by the FAO. In the Indian state of Tamil Nadu, average calorie intake was only c.1,500 kcal/capita/day over the decade 1960/69, but the crude death rate of 19 per 1000 was similar to that of states with average intakes of 2,000-2,300 kcal. Similarly it has been shown that an active healthy community in Ethiopia had an average consumption of only c 1550 kcal/day, a value some 785 kcal less than the average requirement proposed by the FAO/WHO. Surveys of calorie intakes in villages in two Indian states during severe drought periods in the 1960s showed that the average in ake in some villages fell to 1,450 and 580 kcal/capita/day, and although malnutrition was evident, no deaths from starvation was recorded. Estimates have been made of mortality rates in towns in the drought zone of Ethopia in 1973, and extrapolation from these figures, suggests that a fall in the average daily intake of the poorest groups to below 1,000 kcal was accompanied by a rise in death rate from 25 to between 44 and 63 per 1,000. Some of this field evidence has been used in Fig 6 to plot crude death rate against average calorie intake, and it clearly shows that although communities may survive at intake levels below the minimum suggested by the FAO/WHO, crude death rate does rise with decreasing energy intake.

The field evidence indicates that people can survive on intakes below the value for the basic metabolic requirement suggested by the FAO/WHO, but it is not possible to define the average critical intake level, below which death occurs, and therefore to complete the calorie intake - mortality relationship we have taken alternative estimates of 400 and 800 kcal/capita/day as the minimum rates consistent with survival. Thus assuming a normal distribution, and to be consistent withthe limited field evidence on starvation, we set the standard deviation for these critical levels at 300 and 100 respectively. This relationship is superimposed on Fig 6. It is also plotted in Fig 7 to give the propo tion of the population whose calorie intake falls below the survival level, and in this form enters the algorithm for determining mortality levels. In these simple models no allowance is made for the reduction in population from deaths by starvation, nor for the proportionately greater mortality which would occur amongst yound children. Feed back loops of this type are however considered in the main model.

Scenario Development A variety of scenarios have been considered. One of them assumes that aid to foodproduction and domestic investment in agriculture is maintained at about the level in recent years, and income distribution does not change from the present pattern. The iterative procedure used to develop this scenario is summarised in Fig 8 and given in more detail below.

1 Compute population by multiplying the figure for the previous period by the selected growth rate

2 Take the estimated vegetable food production per capita per day from the previous time period, and multiply by the population to obtain the desired total food output.

3 Estimate the cost of this output from the optimal development pathway.

4 Calculate GDP using 0, 3 or 4%/yr growth rate

5 Calculate % GDP devoted to food production from 3 and 4

6 Extract from Fig 2 the mean daily per capita energy intake corresponding to this % GDP on food production

7 Adjust value (of step 2) by iteration of steps 2-6 until per capita intake is in balance with estimated fraction of GDP on food production

8 Scale adjusted value (of step 2) by fraction for country concerned relating total food consumption (vegetable plus animal) to the vegetable component.

9 Using Fig 5 estimate fraction of population expected to receive less than selected daily energy intakes.

Under this scenario the combination of increasing population and rising price of production inputs, together with the diminishing marginal return to agricultural inputs, results in an increasing proportion of the GDP going to food production, and higher food prices. The rate of increase in this GDP proportion varies according to the assumed value for economic growth, and values of 0, 3 and 4%/yr are tested. Many people in these countries already spend all or much of their income on food, therefore given increased food prices and no or little real growth in per capita income, it is assumed that mean calorie intake of the population will decline in accordance with Fig 2. This nutritional deterioration occurs for all the combination of parameter values examined, although of course the rate varies. Up to 2010 AD for any of the parameter combinations examined, there are no marked differences in mean intakes for two alternative rates of population growth, namely continued growth at the rate prevailing during 1969-71, or at the slowly declining UN median rate, and therefore only the results for the constant growth rate are presented here.

Table 1 gives the results for certain parameter combinations. Assuming zero growth in GDP and in the cost of production inputs, the average calorie consumption in India drops from 1990 to 1700 kcal by the year 1990 (Table 1 column 1), and at this average intake, 62% of the household have mean consumption levels below this calorie intake, ie below the FAO value for the maintenance requirement. The projections in Table 1 show that given poor economic growth, recurrent starvation may become pandemic in Bangladesh on an increasing scale from the 1990's with India and Pakistan lagging behind but relatively soon following a similar pattern.

Table 2 shows the number of people who would die of starvation in Bangladesh on the two alternative assumptions of the minimum intake of food energy necessary for survival, and for different economic parameter values. There is a marked escalation of annual deaths given the assumption of a 2%/yr increase in production input prices associated with zero GDP growth, with a projected annual death rate from starvation of c.5.5 million in the year 2010. India and Pakistan would have lower death rates at the turn of the century, but would follow a similar path to Bangladesh in the first two or three decades of the 21st century. Death rates of this magnitude would have a rapid feed-back on net population growth, although this is not allowed for in these projections. These sub-models only consider a smoothed 'annual expected' death rate from starvation, and hence do not present the violent fluctuations about the mean which would occur as a result of weather induced variations in food output etc. Famine already occurs from time to time in localised areas, but the projected annual 'expected' deaths across the whole country are much more formidable.

Application of the UN median forecast of population growth, instead of the exponential one used for the projections in Table 2, would present a less severe picture up to the year 2010, but similar effects would eventually arise. The outlook would be much worse if the FAO value for minimum food energy intake were accepted, and also if agricultural development failed to follow the optimal path. These results are less pessimistic than those put forward by Mesarovic and Pestel, who suggest that the total number of children dying from starvation in these three countries may be c. 13 million/yr by the year 2010. These workers use a linear relationship between food intake below the required level and mortality. This relationship is not supported by the field data on low food intakes and mortality used in our sub-models.

If a sustained high growth rate of the GDP was attained, pandemic starvation induced mortality would not occur before the year 2010 (Table 2, columns 5 and 6). Such a high growth rate appears relatively unlikely in these countries, because approximately half the national output is already devoted to food production, and only a small proportion goes into the production, of exportable goods. Thus substantial growth in GDP would require rapid and continued expansion in these 'trading' sectors of the economies. In the absence of foreign aid such an expansion could probably be attained only by a diversion of investment in productive capacity away from agriculture, and this would induce a worse nutritional situation in the short term even though the long-term effect might be improved. The projected situation would be improved by either large injections of aid, or a marked decline in fertility, and parameter changes of this type are to be examined in our World Model.

The food study of the Indian sub-continent was an exercise in sub-model construction with the system boundary drawn at the frontiers of the countries. Within the system - the physical relations governing increased food production and the economic balance tending to lower calorie intake as faction of GDP on food production rises - are modelled. The exogenous inputs to the system are:-

1. Population increase rate
2. The price change of inputs to agriculture
3. The growth rate of the economy

Clearly, it is more satisfactory if the exogenous inputs can be reduced in number. The price change of nitrogenous fertiliser is related to the price of energy needed to manufacture it and this in turn is related to the extent of depletion of fossil fuel reserves and the cost of substitute energy sources. The growth rate of the economy is related to the level of investment, to the increase of productivity and to the trading position of the country relative to the other countries of the world.

It follows therefore that in order to reduce the area of speculation, individual sector models for energy, fertiliser etc are needed operating within countries or within groups of countries and linked not only within economies through money and material flows but also between economies through trade.

This is a modelling operation nearing completion in the Systems Analysis Research Unit. Because there is a diminishing returns aspect to the disaggregation process, the level of disaggregation can be varied. Finer separation requires more data, carries more risk of error, takes longer to program and costs more for each run. The return for this extra effort is more detailed and more precise output. However, the increase of precision and detail falls off with greater disaggregation and so a compromise is struck. The current levels of disaggregation are:

3 groups of economies
10 sectors within each

The sectors are	capital goods	non-food crops
	consumer goods	vegetable products

energy	animal products
agricultural services	processed vegetable products
minerals	processed animal products

The detail in this sectoral classification deliberately emphasises food because the pressure on food supply is greater than on any other resource such as metals or energy.

This 3 stratum, 10 sector model operates successfully with partially validated data. It is demand driven, the prices finding values that the market will bear, within the economies. The production functions are subject to both technical improvement, and depletion effects such as the greater difficulty of securing energy, minerals, water and cultivable land, Investment occurs according to the profitability of the individual sectors. The migration of labour between sectors is driven by the wage differential. The fraction of total output paid to labour is a function of the level of employment. Thus the full range of economic feedbacks operate and the model displays robustness to perturbations.

The structure of the model provides a test bed for the simulation of a variety of actions which go beyond the idealised market equilibrium state. Using the basic version, effects of cartel action, trade embargos, advance action to provide substitutes, alteration to fertility rate, changed levels of aid and shifts in income and distribution can be separately tested. The requirements for creation of this basic test model have needed the development of several techniques which are new to the modelling field. In particular, the derivation of a trade barrier matrix to represent the relation between expected and actual trade flows is a novel concept. The quantification of degree of anticipation necessary to provide timely substitutes is an innovation.

It is our view that this basic structure provides, not merely another model but a generalised modular mechanism capable of being used by a range of investigators to experiment with practically the whole range of parameter variation, that may be desired, at any appropriate level of disaggregation. The program modules will be available in early 76.

FIG. 1 DIMINISHING MARGINAL RETURNS TO USE OF PRODUCTION INPUTS IN DIFFERENT AGRO-CLIMATIC ZONES

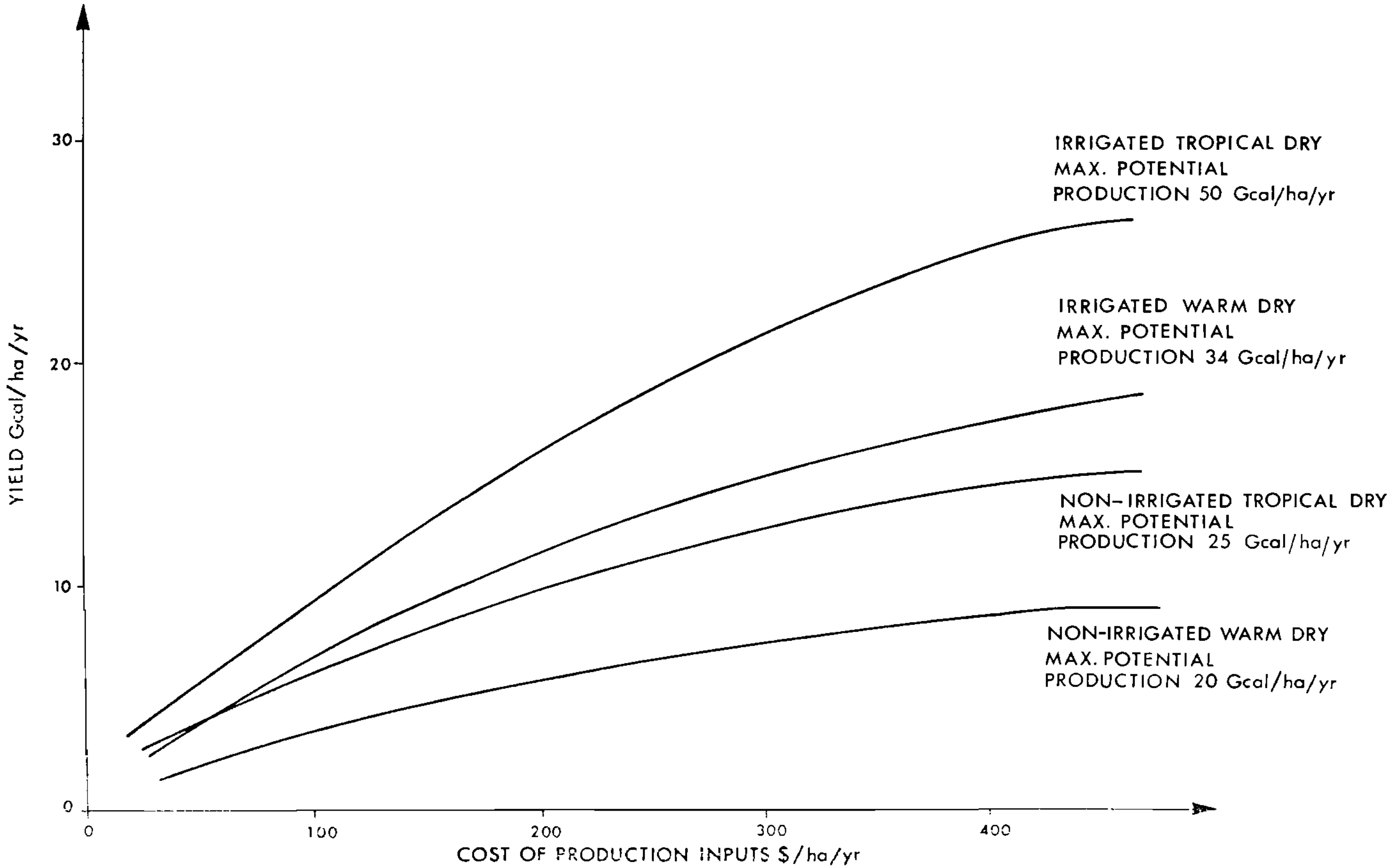

FIG. 2 RELATIONSHIP BETWEEN NATIONAL EXPENDITURE ON FOOD PRODUCTION AND FOOD CONSUMPTION

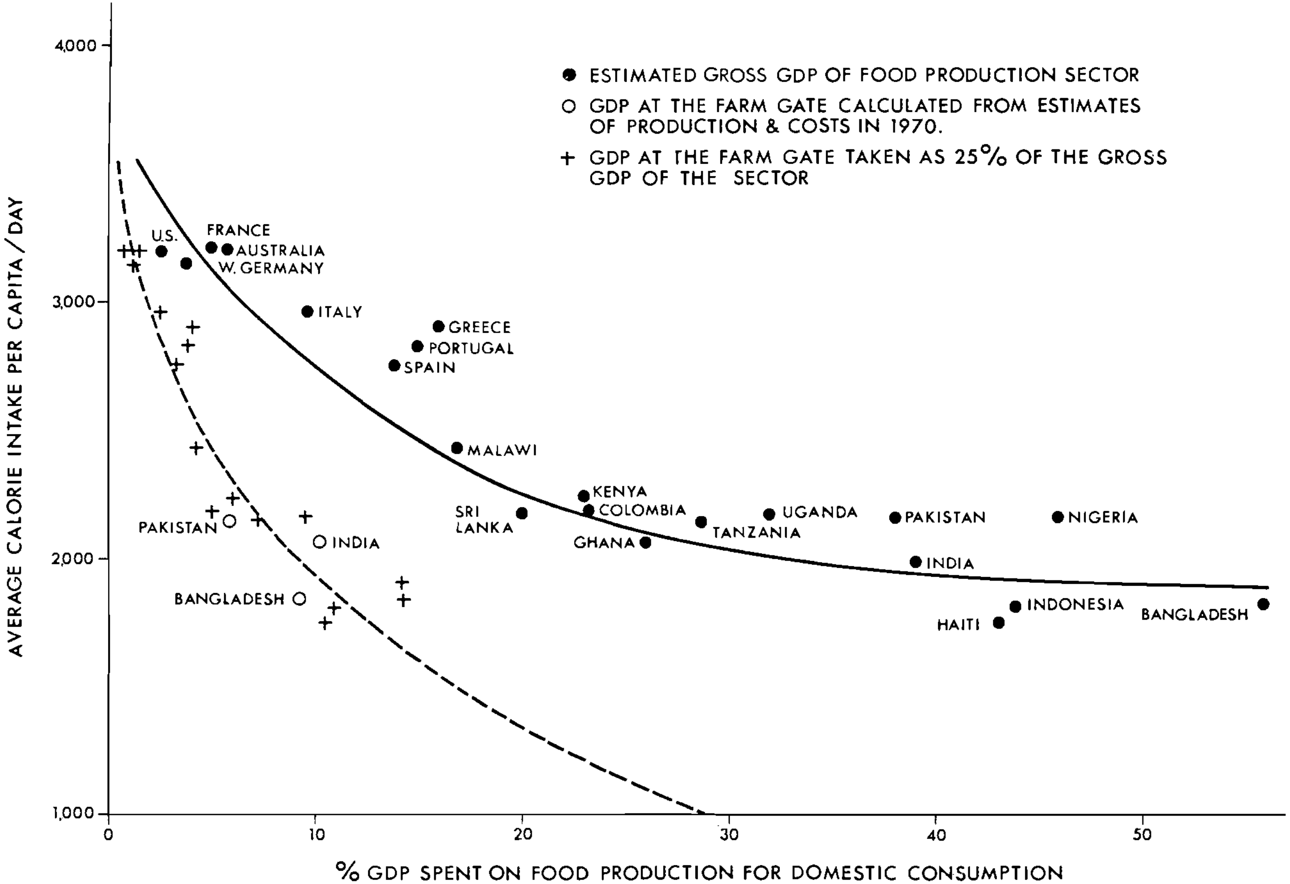

FIG. 3 DISTRIBUTION OF CALORIE INTAKE FROM SURVEYS REPORTED BY FAO
(SURVEY DATA SHOWN IN SOLID LINES BY HISTOGRAMS, NORMAL APPROXIMATIONS SHOWN BY BROKEN LINES)

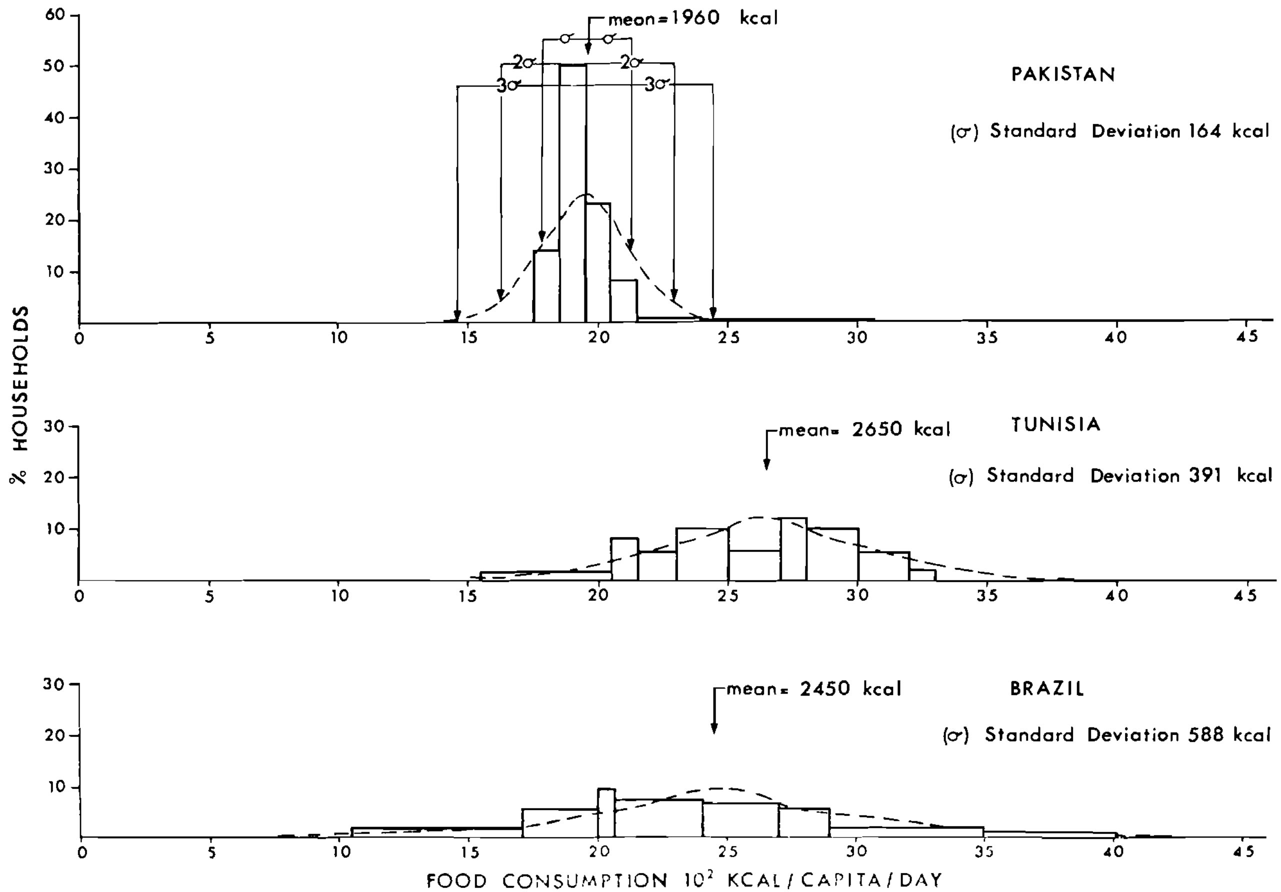

FIG.4 RELATIONSHIP BETWEEN NATIONAL AVERAGE CALORIE INTAKE AND STANDARD DEVIATION AMONG HOUSEHOLDS

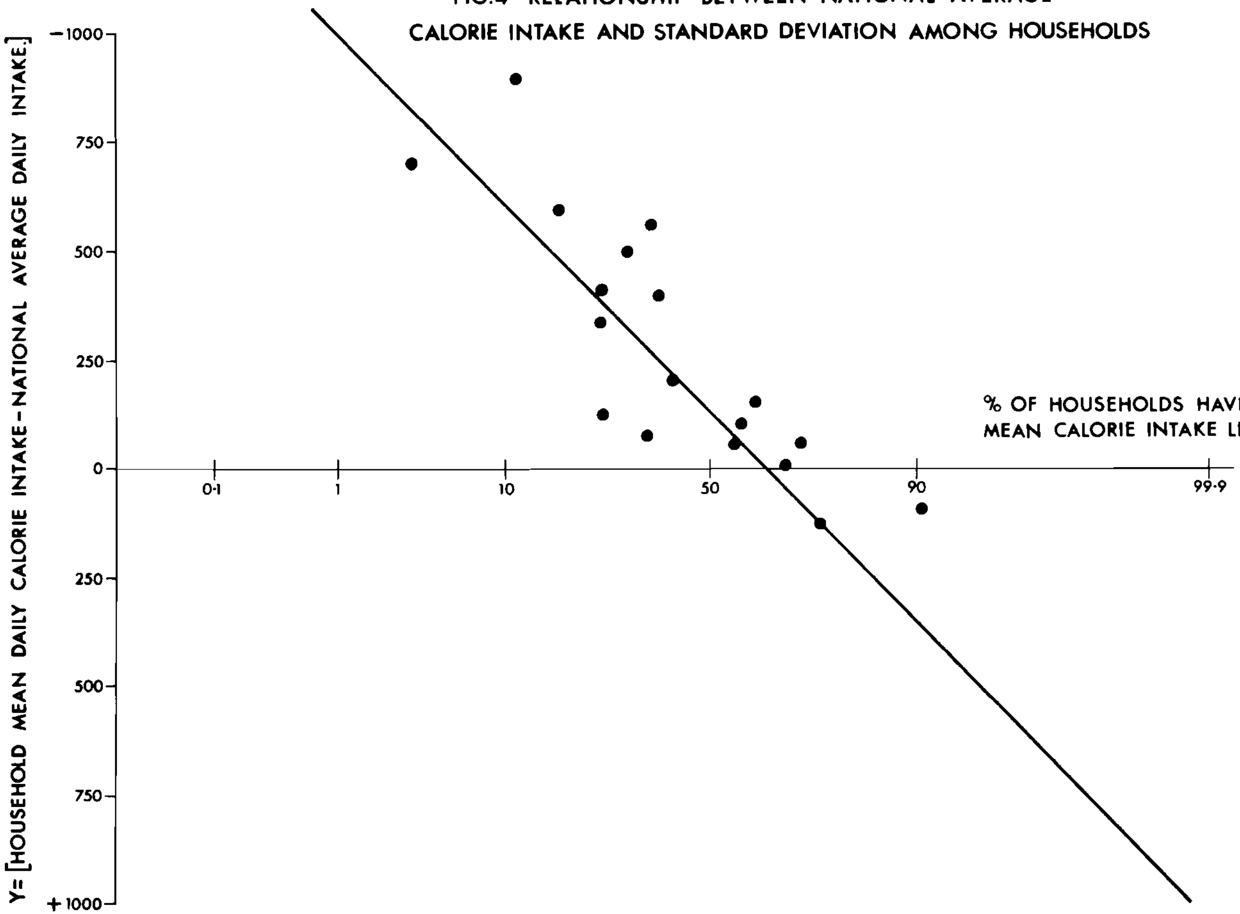

FIG.5 PROPORTION OF POPULATION FALLING BELOW VARIOUS LEVELS OF CALORIE INTAKE, AS A FUNCTION OF AVERAGE INTAKE FOR A POPULATION

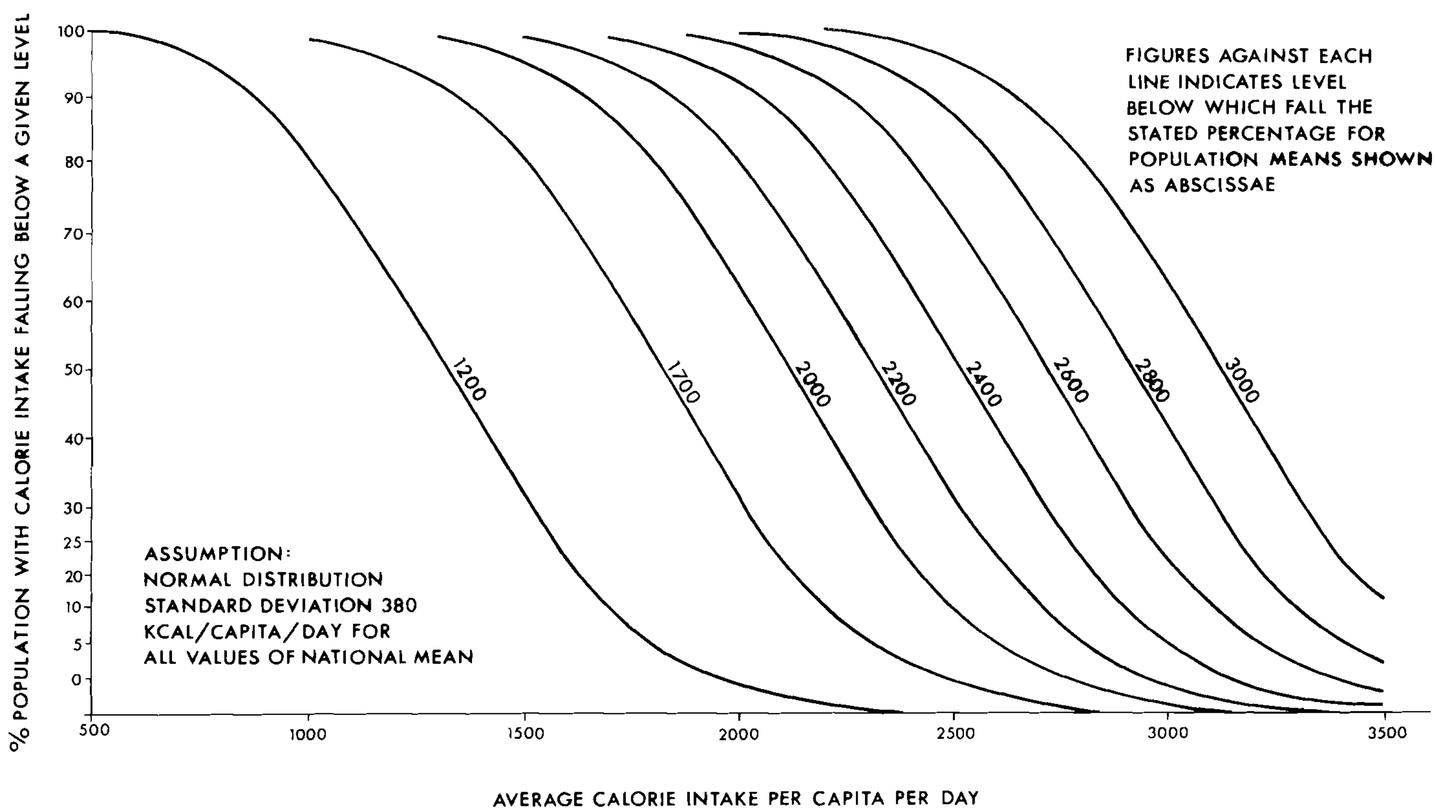

FIG. 6 RELATIONSHIP BETWEEN REGIONAL OR NATIONAL AVERAGE CALORIE INTAKE AND THE CRUDE DEATH RATE

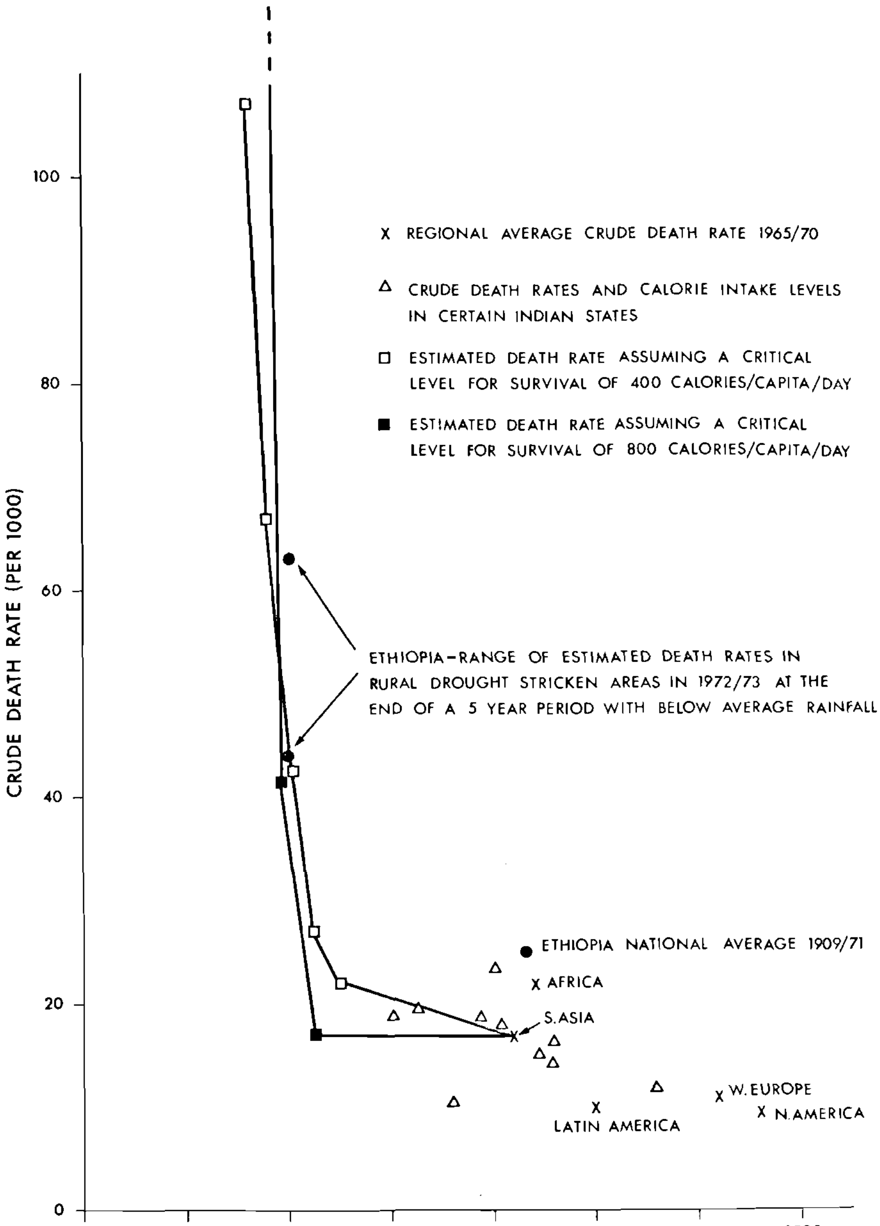

FIG.7 PROPORTIONS OF A POPULATION WHOSE CALORIE INTAKE FALLS BELOW ALTERNATIVE CRITICAL LEVELS AT DIFFERENT VALUES OF AVERAGE CALORIE INTAKE AND STANDARD DEVIATON

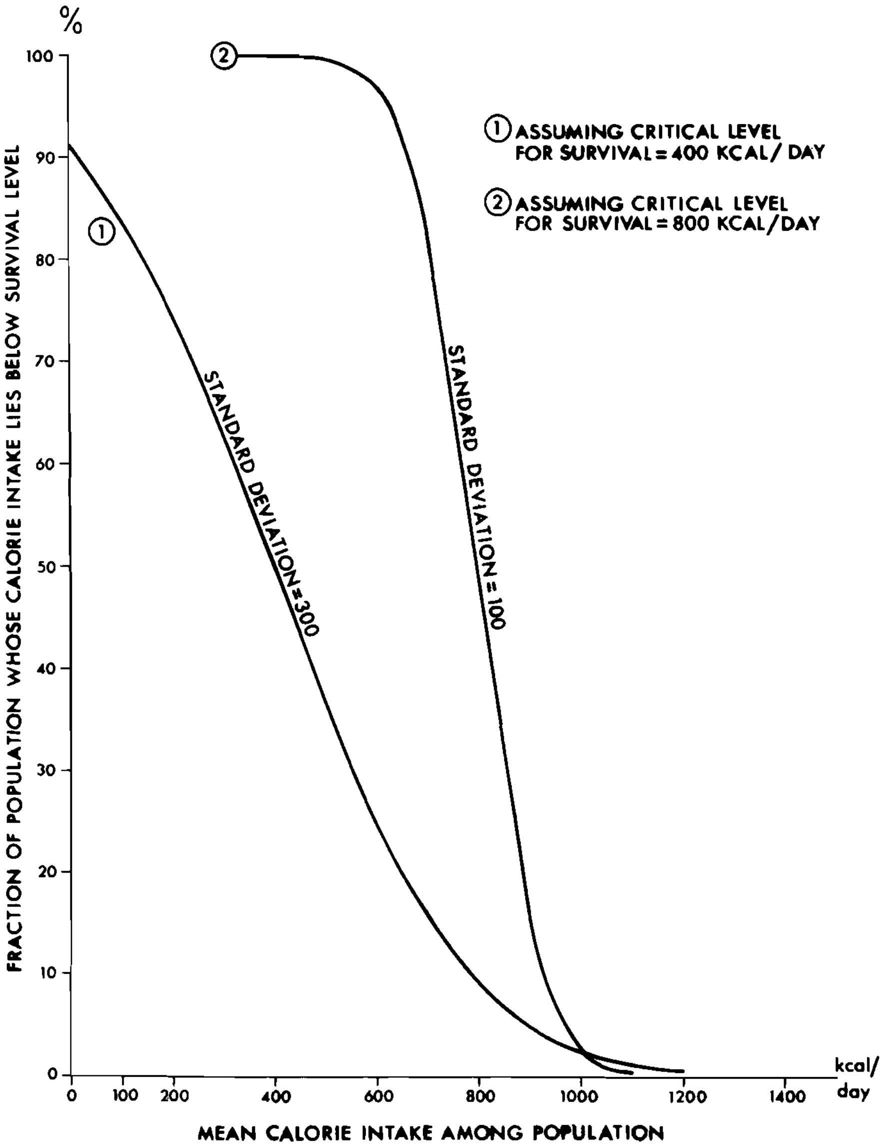

FIGURE 8

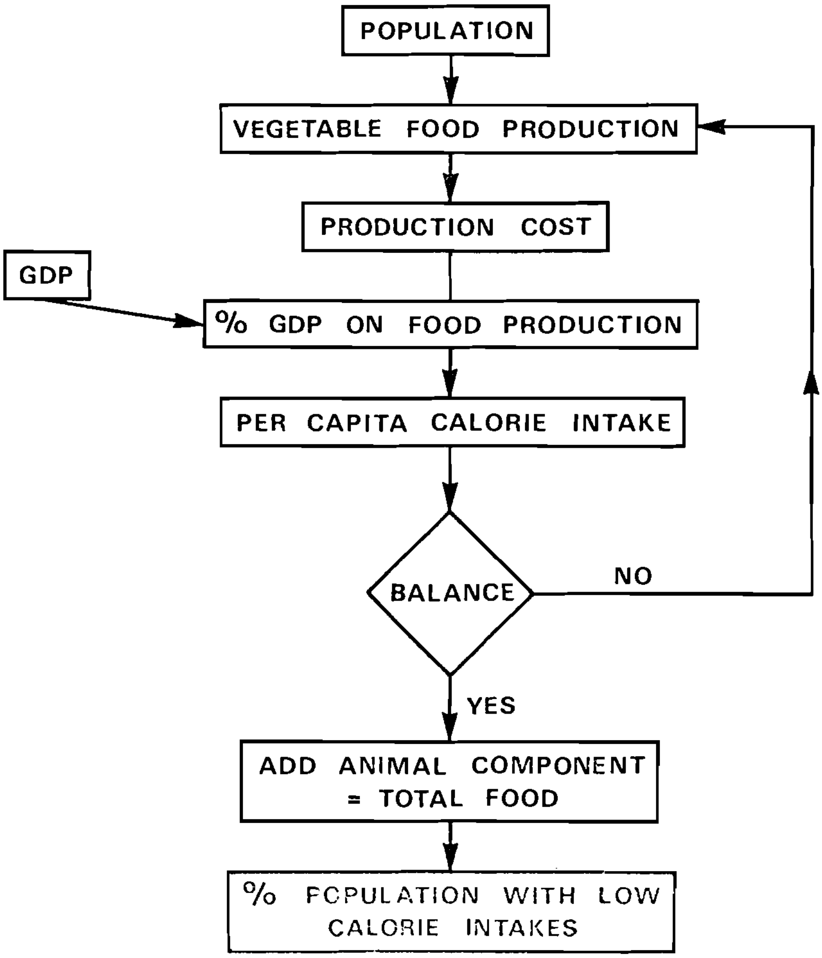
POPULATION
VEGETABLE FOOD PRODUCTION
PRODUCTION COST
GDP
% GDP ON FOOD PRODUCTION
PER CAPITA CALORIE INTAKE
BALANCE
NO
YES
ADD ANIMAL COMPONENT = TOTAL FOOD
% POPULATION WITH LOW CALORIE INTAKES

TABLE 1

PROJECTIONS OF MEAN CALORIE INTAKE

		MEAN CALORIE INTAKE (kcal/capita/day).		
		CONSTANT (1970) INPUT PRICES. ZERO GDP GROWTH	2%/yr INCREASE IN INPUT PRICES. ZERO GDP GROWTH	2%/yr INCREASE IN INPUT PRICES. 3%/yr GDP GROWTH
INDIA:	1970	1990	1990	1990
	1990	1700	1600	1880
	2010	1420	1280	1765
BANGLADESH:	1970	1840	1840	1840
	1990	1515	1440	1690
	2010	1110	1000	1460
PAKISTAN:	1970	2160	2160	2160
	1990	1860	1740	2010
	2010	1520	1300	1830

TABLE 2 PROJECTED NUMBER OF DEATHS FROM STARVATION IN BANGLADESH UNDER DIFFERENT PARAMETER ASSUMPTIONS

	NUMBER OF DEATHS					
	CONSTANT (1970) INPUT PRICES. ZERO GDP GROWTH		2%/yr INCREASE IN INPUT PRICES. ZERO GDP GROWTH		2%/yr INCREASE IN INPUT PRICES. 3%/yr GDP GROWTH	
CRITICAL LEVEL (kcal/capita/day)	400	800	400	800	400	800
STANDARD DEVIATION	300	100	300	100	300	100
1970	<100	<100	<100	<100	<100	<100
1980	600	"	1,300	"	200	"
1990	13,000	"	40,000	"	1,100	"
2000	240,000	"	700,000	400,000	8,700	"
2010	2,200,200	240,000	5,600,000	5,600,000	57,300	"

SECTORAL CLASSIFICATION OF THE WORLD MODEL

CAPITAL GOODS	NON–FOOD CROP PRODUCTION
CONSUMER GOODS	FOOD CROP PRODUCTION
PRIMARY ENERGY	LIVESTOCK PRODUCTION
MINERALS	LIVESTOCK PROCESSING
AGRICULTURAL SERVICES	FOOD CROP PROCESSING

Discussion

Bottomley asked whether the fertilizer response curve used was in fact obtained from trials or from actual real-life experiences. In reply, Norse stated that trials were carried out on farms by farmers. Parikh added that methods for carrying out these trials differed greatly, from specialized farming techniques on one hand, to simply copying the manner in which the field worker puts fertilizer on the ground. At his institution, they have much experience in this respect.

Richardson stressed that the paper is more optimistic as to the extent of starvation than other papers previously presented by other participants. He wondered how this optimism would be reflected in recommendations to policy-makers as to population control, the desirability of agricultural development and so forth, and whether these policy recommendations might differ significantly from the recommendations that were presented or might have been derived from other ventures such as "Mankind at the Turning Point".

Other speakers doubted the validity of the low calorie requirement expressed in the paper, especially owing to the often weak statistical data base. Furthermore, there is a distinct time lag from consumption to undernourishment, and from undernourishment to death from lack of food; undernourishment may also lead to an increase in diseases that result in death at a later period of time.

Rossmiller found it disconcerting that population is an exogenous factor in the model.

In reply, Roberts pointed out that, in arriving at policy recommendations, one should be aware from the beginning of the necessary weakness of certain model assumptions. Bearing in mind these restrictions, he believed that the main findings of his model did not differ from those of "Mankind at the Turning Point". Even though his results may be less pessimistic than those of "Mankind at the Turning Point", he considered the situation quite dramatic, so the basic message of both models remains the same.

From Development to Implementation: Activities Of the Mesarovic-Pestel Project During 1974-75

John M. Richardson, Jr.

ABSTRACT

The paper discusses the implementation of the food submodel of the Mesarovic-Pestel project. The model, which follows a regionalized and multi-level approach, was presented at the first Global Modelling Conference held in 1974.* Among the major conclusions of the study are the following:

An intelligent and effective population policy must be an integral part of any strategy designed to deal with the potential food crisis;

For optimal economic development there must be a balance between agricultural and non-agricultural sectors;

A program of assistance to solve the food crisis in South Asia is essential; although large-scale assistance is needed, the amount is not prohibitive.

The system was presented at a meeting of the Club of Rome held in Berlin in 1974, and also at the meeting of the members of the European Parlament in Hannover in 1975. Reference is made to the successful implementation of the model in Iran.

Some observations are given on organizing large-scale modelling projects:

Once the model has been completed, the group that developed it should continue to work together;

It is important to strive for acceptance of the results both in the scientific and in the decision-making community;

At every stage the program must be able to produce demonstrable results.

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*M. Mesarovic and E. Pestel, eds., *Multilevel Computer Model of World Development System; Summary of the Proceedings*, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1974.

Discussion

Bottomley stated that in his paper Richardson raised an interesting point: how can one resolve the dilemma created by the fact that on one hand, there should be an optimal exchange of information among modeling groups, on the other hand, modeling groups should be as independent as possible in identifying and establishing their priorities. Richardson answered that part of what makes a project successful is the group spirit, the mutual confidence and the willingness to work and to make sacrifices of individual identity among the members of the group. Whenever a group that has worked together successfully is dissolved, the loss of the team work is greater than the loss of factual information. It was his experience that it can take up to a year to establish this common spirit.

Randers added that one should not overlook the difficultyof administrating an interdisciplinary study; this goes beyond the usual problem of fitting together people of different personalities. In this respect, one can certainly learn from experience.

Roberts stated that, in principle, he wholeheartedly agreed with all that has been said so far. The only counterpoint he would like to make is that it is positive to have a variety of approaches, often from totally different backgrounds. He therefore hoped that the constructive spirit exhibited by present groups will encourage the formation of new groups, possibly from an entirely different angle. These new groups should learn as much as possible from the information gathered by other groups; hence, no group should construct a model so complex that another group could not understand the lines of reasoning.

In reply to a question by Cole, Richardson stated that different institutions will take a particular model and use it for different purposes. This practise should not be condemned; the more facts available, the better off one will be, irrespective of how these facts are being used.

In reply to a question by Brioschi, Richardson outlined the main difference between his approach and that of MOIRA. An obvious main difference is that his food model forms part of a much larger global model that has a well-defined economic sector, a population model and so forth; all of these are linked to the food and agricultural sector. Secondly, his model is essentially a supply-driven model, as compared to a demand-pull model such as MOIRA. Thirdly, MOIRA goes farther in investigating the functioning of a world market; in his model, specific regional issues were considered more important. For his model, there remains much to be learned about further integrating food and energy from the demand structure. Of course, there are more technical differences in his model, for instance, the definition of the production function, but that is not basic. Furthermore, his group worked hard at comparing model outcomes with historical results: this was a great help in calibrating and estimating the parameters. As a result, they are more confident that what the model is doing must be reasonable.

Food Problems and International Trade in Cereals

Gilbert Etienne

SOME FEATURES OF THE WORLD MARKET IN CEREALS

World output of cereals increased from 1228 million tons in 1974 to 1246 million in 1975 and about 1300 to 1350 million in 1976. Between 1971 and 1974, the total amount of wheat on the world market was about 60 million tons per year; production figures during this period for coarse grains such as maize and millet were 60 to 70 million tons per year, and for rice about 7 million tons per year. Imports of maize and millet by developing countries (China included) are relatively small (about one fifth to one third of the total world figure). For rice, developing countries imported three quarters of the total amount on the world market. As to wheat, the share of the third world oscillates between 30 to 40 million tons while advanced countries import around 23 million tons (excluding the USSR).

In spite of the improved situation in 1975 and 1976, the world food supply remains a matter of great concern, because agriculture is still vulnerable to sharp weather variations especially in the third world. Two major questions have to be raised, especially with regard to the third world: availability of grain on the world market and prices. Table 1 shows data on world reserves for 1971 to 1976.*

Table 1. World reserves held by main exporting countries (available before next agricultural year), 1971-1977.

(millions of tons)

	Wheat	Rice	Other Cereals
1971/72 (July-June)	52	6	56
1972/73	33	4	40
1973/74	29	4	29
1974/75	32	4	24
1975/76	37	5	25
1976/77 (forecast)	52	5	32

The decrease in world reserves until 1973/74 is owing to the massive grain imports by the USSR in 1972/73 (20 million tons of wheat and 10 million

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*Most data comes from FAO reports E/CONF 65/3 and 65/4 (World Food Conference 1974) and from later FAO reports.

tons of coarse grain), and to simultaneous crop failures in Asia and Africa. The poor harvests of wheat and maize in the USA in 1974 did not allow for a substantial improvement of the situation. Wheat crops in the USA in 1975 and 1976 have been very good; maize also did well. The Soviet Union has faced a severe deficit in 1975 which led to the import of 10 million tons of wheat and 13 million tons of coarse grain during 1975/76. Forecasts for imports in 1976/77 are respectively of 6 and 5 million tons, owing to good harvests in 1976. The situation has also improved in Asia.

The decrease in the amount of grain reserves has been aggravated by price trends. Since the mid-1950s and until 1965 or so, US food aid (Public Law 480) has covered 30 to 45 percent of total imports of cereals by developing countries. Many countries, particularly those of Asia, were able to cover the bulk of their grain deficit and thus to escape famines. Such supplies were very favorable for the receiving parties, since they involved gifts and/or supplies paid back mostly in local currency. In addition the proceeds of the sales within the country would be lent by the US Government to the local government for development projects. For example, in the case of India in 1974 the USA has given up their claim to repayment of loans.

As a result of these grain supplies, third world countries largely escaped the consequences of grain price fluctuations. Here again the situation has drastically changed since 1972, in spite of some improvement since 1974, as can be seen in Table 2.

Table 2. Food aid and sales.

(million tons per year)

Country exporting	1960/61-1964/65	1965/66-1969/70	1971/72	1972/73	1973/74	1974/75	1975/76
USA	15.6	12.80	9.53	6.92	2.98	4.57	6.35
Canada	0.18	0.67	0.60	0.71	0.50	0.73	1.00
EEC	-	0.56	1.03	1.25	1.22	1.42	1.28
Japan	-	0.11	0.60	0.44	0.43	0.30	0.22
USSR	-	0.04	0.02	-	2.00*	-	-
Total**	15.84	14.48	12.72	9.81	7.68	8.37	9.46

*Wheat loan to India, to be paid back in kind.

**The figures do not tally with the total because we have not mentioned various minor supplies.

The decrease in the amount of aid given in 1970/71 and 1971/72 may be explained in part by India's reduced grain imports owing to the improved grain situation in that country. Later, Soviet imports had a great impact on US grain policy. It appears senseless to encourage an agricultural support policy within the USA. Thus from 1973 onwards, the US Government has abandoned their policy of storing grain. Cereal trade is now mostly handled by private US firms. The Government grants food aid only under limited conditions (repayable usually entirely in dollars over a 40-year period at a 2 percent interest rate) and usually in an attempt to avoid an emergency in the importing country.

All these factors and world inflation explain the sharp increase in grain prices, even after taking into account the loss of value of the US dollar. However, good harvests in 1976 in North America, the USSR and Asia explain the fall in prices. As to the volume of import, it is falling sharply in 1976/77 in a number of countries--China, India, USSR.

Export Prices (fob in US dollars per t)

June-July	Wheat	Rice	Maize
1971/72	60	133	52
1972/73	92	171	72
1973/74	177	584	116
1974/75	161	439	132
1975/76	151	295	116
1976 Aug.	129	243	116
1976 Nov.	106	260	98

Wheat: US No. 1 winter
Rice : Thailand
Maize: US No. 2 yellow

Price fluctuations do not depend only on the law of supply and demand; speculation also plays an important role. Any forecast of poor crops in a large importing country boosts world prices. The same phenomenon affects export countries. For instance in 1974, maize harvest in the USA was 10 percent below expectations, which has pushed prices up by 60 percent.

Thus some system of world reserves isolated from market prices is needed not for routine imports but to face serious emergencies in developing countries. Although technical difficulties should not be underestimated (cost of storage, localization of stock, controls, etc.), what is lacking in Western countries is the will to act and cooperate. Wealthy socialist countries also have not been particularly helpful. Unless some reserve system is organized, few countries will give early warning of their needs in times of emergency for fear of pushing prices upward. Sound and timely cooperation between rich and poor countries would not be possible.

CEREALS IMPORTS OF DEVELOPING COUNTRIES AND OUTPUT PROSPECTS

South Asia (Bangladesh, India and Pakistan, with a combined population of 750 million) and China (with a population of 800 to 900 million) represent 60 percent of the population of the third world. Until recently, their cereals imports have been equivalent to about one third of the total grain imports of the third world. While these countries currently represent a major element in world grain trade, they should be able to reduce substantially, perhaps entirely, their deficit over the next twenty years or so. The diet of these people should also improve so that acute deficiencies can be eliminated. China is comparatively advanced and has eliminated real misery.*

However, unless these countries reach what I would call a minimum safety level, they may still be dependent on large imports in the event of bad natural calamities. Situations such as this may be very serious if, as has happened, several large importing countries have had poor harvests in the same year.

South East Asia is in a more favorable situation. Some countries have been net grain exporters (e.g., Burma and Thailand); Indonesia may reach self-sufficiency, even though some years ago they had a deficit of 0.8 to 1 million tons of rice. Malaysia could also achieve self-sufficiency.

In the Middle East, cereal problems are not too serious. Several countries can afford grain imports. A fairly large agricultural potential exists in Iran, Iraq and Syria.

In Africa north of the Sahara, a deficit of a few million tons of cereal may last for a fairly long time. Egypt has already had somewhat high yields per ha. Various physical constraints are slowing down progress in the Maghreb countries.

The prospects in several parts of Africa south of the Sahara are more serious. The Sahel countries face a difficult future when one looks at population increase and the agricultural potential, and the very severe physical constraints. In 1973/74, during the famine, the imports of the Sahel countries reached 1.7 million tons. Such situations may appear again. In other countries located in the west, the center and the eastern part growth prospects are on the whole better, but they may take a long time to materialize: considerable efforts have to be made in the areas of administrative structures research, surveys of rural societies, etc., in order to improve the situation. In both North and South Africa, imports have increased from 1.6 to 7 million tons per year over the last ten years. Thus there is an urgent need to introduce more efficient agricultural policies in many of these countries.

In Latin America, the situation appears more favorable. In several countries (e.g., Mexico, Equador, Venezuela, Peru, Brazil) substantial growth is taking place and the overall development level is higher than in Southern Africa.

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*See G. Etienne, Foodgrain Production and Population in Asia: China, India, Bangladesh, in *World Development*, Oxford, 1977. I made also some estimates on Pakistan and Bangladesh in Le club de Rome et l'Asie: mort ou survie, *Esprit*, 2 (1975). In the following pages, I did not refer to the potential growth in North America and Western Europe. The recent book by J. Klatzmann *Nourrir dix millards d'hommes*, Paris, Presses de France, 1975, shows the potential in rich countries as well as in developing countries.

In summary, although self-sufficiency in food grains will not be reached for all countries (in fact, it is not needed where there is diversification of the economy and the export sector grows fast enough) there is no reason to be too pessimistic. Regardless of political options, there are many possibilities for agricultural development. They involve more common sense, more and better organization and planning, a heavy concentration on agricultural research and agricultural inputs and sound price policies for agricultural commodities and inputs. One can also reasonably hope that, within the next twenty to twenty five years, population growth will slow down; this is already taking place in some developing countries, e.g., Sri Lanka, Malaysia, the province of Taiwan. More efficient family planning policies should be carried out especially when recent experiences are taken into account.*

THE MECHANISMS OF FAMINES

Until the last century, people died of hunger mostly because of a lack of grain. The growing expansion of money in rural areas under colonial rule, and more so in the last decades has increased the importance of the price factor, since a growing number of rural people are paid partly or entirely in cash, as opposed to in kind.

One of the worst famines of this century was the Bengal famine in 1943 where, out of a population of 60 million, 1.5 to 3 million died of hunger. Grain stocks were no doubt low, but what was responsible for the starvation was the price of the grain which increased tremendously under the pressure of speculation, hoarding, etc.

On the other hand, during the two consecutive years of very severe droughts in India (1965 and 1966), only a few isolated cases of starvation death were recorded. The Indian Government received ample supplies from abroad, mostly from the USA under P.L 480. (A total of nearly 18 million tons grain was imported during this two-year period.) The Indian administration organized the food distribution in a remarkable way: fair price shops were open where grain was sold on ration, covering part of the needs of the people, very poor people frequently received some free supplies. Such measures prevented an escalation of prices on the free market.

These examples illustrate the kind of cooperation between rich and poor countries that can be successful: generous food aid from grain-rich countries, and an efficient system of distribution, particularly at the local level which is also very important. In 1974 in Bangladesh, for example, foreign deliveries were large, but, for a number of reasons, the authorities could not reach the required efficiency in distribution; hence, there were many deaths from starvation. Similar shortcomings have appeared in Africa

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*A more sober approach to population problems is needed than currently exists. It is, for instance, wrong to speak of failure in India and in other countries. Such changes do take time, and even in China, population control is far from complete, especially in rural areas where about 85 percent of the population live. However, in an increasing number of countries progress is noticeable.

over the last few years, although foreign responsibility is by no means small. Obviously, the administrative machinery in various developing countries needs to be improved and strengthened in order to avoid other disasters. In such matters, foreign cooperation can only play a limited role.

THE RICH IMPORTING COUNTRIES

A number of rich countries (both capitalist and socialist) are, or can be, sizeable importers of grain. Unlike developing countries, they buy grain not to consume directly but to feed cattle, pigs and chickens. Thus, they absorb considerable amounts of grain: about 6 to 7 kg of grain are needed to produce 1 kg of beef, about 3.5 kg of grain to produce 1 kg of pork, etc. About 370 million tons of cereals are used per year to feed animals in rich countries (30 percent of the world population, socialist countries included); this is more than the total amount of grain consumed directly by the combined population of China and India (1.4 to 1.5 billion).

If protein needs are rated 100, as does the FAO, actual consumption for rich countries averages 123 (i.e., 123 for Western Europe, 126 for North America, and 127 for Eastern Europe and the USSR). Such a situation is absurd. For example, a recent survey has shown that in Switzerland about 50 percent of the male population in the 30 to 39 age group are overweight, and in the 50 to 59 age group, this figure is 78 percent; about 30 percent of the women in the 40 to 49 age group are overweight.*

It appears high time for rich countries, no matter what their ideology, to behave in a more sensible way, so that people reduce their weight for health reasons and outlook! At the same time, their reduced intake of food would increase the supply of grain to the underfed people of the world.

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*Sample survey by Institut d'analyses de marche, I.H.A., Hergiswill, *La Suisse*, Geneva, May 29, 1975. Similar conclusions can be drawn from several surveys made in the USA and in other countries.

Discussion

Karsky noted that he found the presentation by Etienne stimulating. However, he wondered whether a reduction in the consumption of food of the industrialized nations would automatically lead to an increase in the availability of food for the developing countries. A decrease in food consumption in the industrialized nations might simply result in an economic crisis.

In reply, Etienne agreed that the problem is not simple; on the other hand, the overnutrition in the industrialized countries is absurd. The establishment of food reserves for emergencies seems to be of utmost importance, since many countries have not reached a minimum safe level of production. If, for instance, a major crop failure should occur in a few Asian countries, there might be an acute food shortage.

Weber remarked that famine was not new; there have been famines far back in history, the last real famine in Europe occurred in Ireland in 1846. Furthermore, he observed that until now all papers have overlooked the fact that a substantial part of the caloric intake is in the form of beverages; in France, for example, it accounts for as much as 10% of the total caloric input. And if a human society produces more food than it needs, the excess is converted into beer, wine, whiskey, and the like. Thus one cannot speak of an absolute maximum caloric intake. Why should the American of tomorrow not wish to eat steak for breakfast, lunch and supper? Every society with an excess of food has so far invented its own particular type of waste. Bottomley elaborated on this idea stating that this "societal waste" could be considered an emergency reserve. One may even say that the more waste there is, the higher the hidden reserve.

Sanderson mentioned the most disturbing fact that food production in Bangladesh has been decreasing rather than increasing over the past twenty years. Unless the phenomena at work in Bangladesh can be better understood, the country will remain a major candidate for food aid for a long time. Parikh added that only a very careful and detailed study can reveal what might have been the decisive factors lacking in different parts of Bangladesh.

Questioned by Rademaker why the plans exposed by Etienne were not realized in Pakistan ten years ago, Etienne replied that, during the past twenty years, it was believed that the main obstacles were institutional factors. Thus the main concern was for institutional change, not only in Pakistan but also in India and many other countries. During that same period, technical factors such as seed, fertilizers, and other inputs were badly neglected. Once these factors were given proper attention, big leaps forward can be observed--for example, an improved irrigation system in Pakistan, in combination with the introduction of Mexican wheat. As a result, food grain output in Pakistan expanded by 100% over the last ten years.

Sen added that important technological changes, if made available, might result in sudden increases in output. This possibility often did not exist before the 1960s. Richardson admitted that modelers may often underestimate the significance of technology, although, in most cases, they try at least implicitly to take into account technical changes. On the other hand, those designing technologies often underestimate the cost of implementing them and tend to see potentials as almost certain reality. Most modelers would agree that the technology is available for making these regions self-sufficient with even larger populations than exist now. However, the critical constraints lie in the economic sector, in the infra-structure, in the system of agricultural support, extension and marketing that provide the base, and in the incentives that allow people to use the technology.

Etienne stated that human behavior is hard to depict in a model--one may have farming communities that are extremely clever and dynamic and others that are less so.

Parikh asked to what extent the assumptions of Etienne might have altered the message delivered by MOIRA. De Hoogh replied that if Etienne's assumptions are correct, they have been underestimating the development of production in Southeast Asia, resulting in less net hunger than is shown in the model. He and his collaborators would certainly be happy if they were proven wrong in that respect. In reply to another question by Parikh, de Hoogh said it was not possible for them--owing to the lack of data--to control their model by running it for the period 1930 to 1970. Richardson added that in their model, they ran such comparisons, resulting in rather good agreement between calculated and actual data.

International Food Fund (IFF) Concept†

Nake M. Kamrany

I. Introduction

There appears to be a dissonance between the demand and the supply of food versus the need and the supply of food on the global basis.

$$Sgf > Dgf$$

$$Sgf < Ngf$$

$$Qgf > Rgf$$

This global dissonance between food supply and food need requires examination of the long-term alternatives for the deficit regions and an assessment of their ability to become self-supporting.*

Thus, there is a need for an interim solution to fill the gap (Sfg < Nfg) between now and the time needed for the food deficit countries to reach a state of self-support.

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†Preliminary outline.

*For Illustrative approach see W.W. Seifert and Nake M. Kamrany, *A Framework for Evaluating Long-Term Strategies for the Development of the Sahel-Sudan Region*, Center for Policy Alternatives, Massachusetts Institute of Technology, Cambridge, Mass., December 1974. Also, for an analysis of problem identification and resultant policy implication see Nake M. Kamrany, The Three Vicious Circles of Underdevelopment: The Sahel-Sudan Case of West Africa, *Socio-Econ.Plan.Sci.*, 9 (1975), 137-45.

The idea of an International Food Fund was first presented by me to an IFIAS Project Workshop held at Aspen-Berlin, February 5-7, 1975. This concept had the benefit of reactions by the participants of the workshop*.

I am abstracting from numerous ideas and/or reviews of material on the same and/or similar topics. This is done intentionally for the sake of clarity, simplicity, operationality, and getting to the heart of the subject without undue deliberation and/or esoteric elegance; and for the fear that the idea may get bogged down with too many details and may suffer from compromises.

The basic approach is an incremented or gradual solution toward the world food problem in contradistinction to a total or dramatic solution. We have not achieved world freedom from hunger.

Thus, the problem of global emergency food shortages is identified as the central theme and its solution represents perhaps the most pragmatic approach to the general solution of the global food problem.

As such, we will be linking problems of the immediate time horizon to those of the short term (5-10 years) and the long run (25 years or more) time horizons.

Moreover, we will be linking the micro (country or region) analysis to the macro (global) picture and vice versa.

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*See *The Policy Implications of Food and Climate Interactions*, International Federation of Institutes for Advanced Study and the Aspen Institute for Humanistic Studies, May 1, 1975.

The institutional structure will be that of the establishment of an International Food Fund--whose aim will be to guarantee emergency food requirements to its member nations (membership shall be open to all nations including the materially rich and the materially poor). Such an institution could provide a base for implementing policy implications of innovative research and modeling activities in pursuit of its objectives.

A preliminary cost analysis for IFF has been prepared.*

II. Basic Assumptions for IFF

Note: The global models presented at this conference and other are useful in and modifying some of the following assumptions made about IFF and may provide the necessary insight toward the feasibility of IFF.

1. Over the next quarter century (1975-2000), world population growth rate will be steady, i.e. will be equal to or slightly smaller than the existing rate (birth control measures have largely failed whether they were launched by the public or private agencies, national governments, bilateral aid arrangements, or international agencies).

2. Total world food production will be equal to or greater than the total world food consumption requirements for adequate

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*See P.L. Rogers, *Analysis-Costing of Emergency International Food Fund (IFF)*, paper presented to a Special Studies Seminar on Policy Analysis, Center for Policy Alternative, Massachusetts Institute of Technology, Cambridge, Mass., 1975.

per-capita diet regardless of foreseeable climate fluctuations. (This is actually a very conservative assumption). An optimistic or average assumption could claim that world food production could be substantially increased to support world population of the year 2000 by a factor of X ($X > 1$), especially if new sources of food are included in the assumption plus the observation made that less than 50% of the arable land in the world is in production and the crop yield of drought prone regions could be improvided. Also, measures could be taken to counter agricultural sensitivity to weather conditions, improve malfunction in food distribution, and counter price manipulation by big buyers. The impact of climate technology could improve by the end of this century to counter climatic anomilies although in the next decade, the probability of a substantial cooling from natural causes or a trend toward a warmer climate from human influences is not very high. However, the frequency of droughts on a world-wide basis has increased since 1800, requiring a concentrated effort to counter their direct and indirect effects.

3. Reliance on market mechanism or food grants will not bring into balance (equilibrium) the need for and quantity of food for meeting emergency and minimum per capita food requirements on a world-wide basis. Therefore, a non-market approach to meeting emergency and minimum per-capita food requirements is necessary. (It should be noted that for transactions above the emergency and minimum food requirements we have reserved comments about the appropriateness of the market mechanism).

4. Materially poor countries will aim to reduce and eventually eliminate economic dependence, i.e., they will reach self-support over time. However, the higher food cost, partly due to oil prices and imports of food from long distances, will adversely affect their ability to reach the status of self-support within a reasonable time span.

III. Guiding Principles for IFF

1. IFF will function on the principle of full participation by its member nations. Although the bulk of IFF initial funding would, of course, have come from a relatively few materially rich countries, all member countries should contribute on an equitable basis. A sliding index will be developed for initial and continuing fees.

2. IFF will be a not-for-profit, non-political, autonomous organization. The spirit of detente may contribute to such an organizational structure.

3. IFF might be established at first to provide emergency food assistance, but with the view of moving, if the member nations wish, into a larger role of balancing out surplus and deficit production among participating nations.

4. IFF will draw its annual operating financing from a progressive food tax (all members) and ability to borrow in the fund market with preferential treatment by the fund market.

5. IFF will meet the deficit for minimum per-capita food requirements for countries whose per-capita income falls below a certain level (to be determined) at a fixed cost (to be determined). For countries whose per-capita income is above that level, the

cost will increase until it reaches the market or going price.

6. IFF will purchase its food requirements and may provide price support for needed commodities at a relative price index (e.g. OPEC intended approach for price indexing of oil).

7. Among other things, IFF will carry out a weather and crop monitoring, develop contingency plans for extreme weather conditions both good and bad; including measures for food distribution and storage.

Discussion

Gallopin inquired whether, in the particular case of the Sudan region, Kamrany would conclude that the restrictions are mainly of a socio-political nature. In reply, Kamrany stated that they had investigated many foreign-aid programs, and concluded that they are almost useless, because of limited rainfall, and so forth. It is of utmost importance that those responsible in the region understand the situation and arrive at an agreement to limit the number of cattle in certain parts of the country. This is not unlikely; in many parts of the world similar tribal systems exist whereby tribes come to a compromise on the basis of some understanding of the main problem.

Furthermore, Kamrany stressed that in their model possible climatic adversities have been included, based on information about the last four hundred years.

Swain asked whether possible shortfalls in a particular year would not affect prices and therefore the demand for funds in the International Food Fund. Kamrany replied that such checks were made. Their assumption was that at worst, one would need 17 to 18% of the normal consumption for contingencies, but on the average, 5 to 6% would be sufficient.

World Agriculture: Reassessment of Trends and Policies

Fred H. Sanderson

Introduction

Like other recent studies of the subject, the Brookings project was prompted by the world-wide debate over the nature of the "food crisis." Are current shortages and high prices of agricultural commodities a transient phenomenon, or do they signal a fundamental change in the relation between world food supplies and demand?

As a first step toward answering this question, an analysis was made of the immediate causes of the food crisis. 1/ The analysis shows that the events of the past three years can be explained as the result of transitory factors: an unusual, but not unprecedented, series of crop shortfalls in the USSR, South Asia, and North America; and the failure of the major producing and consuming countries to prepare for such an eventuality. The crisis could have been avoided if the United States and other countries had been more prudent in maintaining grain production and adequate stocks. Between 1967 and 1972, U.S. wheat acreage was cut back from 59 to 48 million acres; U.S. coarse grain acreage was cut from 103 to 96 million acres; Canada's wheat acreage was cut from 31 to 22 million acres. If the acreage had been held at the 1967 level, more than 100 million tons of additional grain would have been available in 1972. If the acreage had been held at the somewhat lower 1968 level, more than 50 million tons of additional grain would have been available -- more than enough to ride out the crop failures of 1972 to 1975 without significant price increases.

1/ Fred H. Sanderson, "The Great Food Fumble," Science, May 9, 1975.

This explanation does, of course, not preclude the possibility that the world -- or major parts of it -- may be confronted with an adverse change in long-term trends of food supply and demand. That fear, recurrent since Malthus, is based on the apparent imbalance between an exponentially rising demand for primary food energy, spurred by population and income growth, and the plausible expectation of diminishing returns from land, water, fertilizer and other inputs. This imbalance should be reflected in rising real costs of food production until food production finally reaches the physical limits of land, water and fertilizer use. Rising real costs, in turn, would impede any improvement in the already inadequate diet of the poor countries and would eventually force even the affluent to cut down on the food-energy wasting conversion of grain into livestock products.

Past Trends

We know that this has not happened. World grain production -- which accounts for three-fourths of the production of primary food energy -- has been rising at a fairly steady rate of about 3% annually during the past quarter century -- well ahead of population growth in the affluent countries, and slightly ahead of population growth in the developing countries (Chart 1 and Table 1).

This growth of world food production was accomplished mainly by raising yields per acre, and only to a minor and diminishing extent, by expanding acreage. In the past 25 years, cultivated acreage did not increase at all in the developed countries as a group while it contributed about one-third of the increase in food production in the developing countries.

Grain yields per acre have been rising at annual rates of 3% in

Table 1

Annual Rates of Growth of Grain Production,[a] Yields, and Population,

1950 - 1973

	Grain Production	Grain Yields	Population
U. S.	2.6	3.8	1.4
Canada	1.1	1.3	2.1
EC-9	3.3	3.1	0.8
Japan	0	2.1	1.2
USSR	3.8	3.1	1.4
Poland	2.7	3.0	1.3
Argentina	3.8	2.3	1.6
Brazil	4.3	0.2	3.0
India	3.6	2.5	2.1
Pakistan[b]	5.6	4.3	3.9
Bangladesh[b]	0.4	-0.5	3.1

a/ Average of first three years to average of last three years.

b/ 1963 - 1973.

developed countries and 2% in developing countries. Contrary to what one might expect, the growth of yields, with some exceptions, has not slowed down (Chart 2), even in the developed countries where they already are high (Table 2).

Increased yields were made possible by technological progress. The "law of diminishing returns" notwithstanding, the net effect of increased applications of fertilizer and pesticides by and large has been cost-reducing. This has also been true of investments in irrigation, drainage, and water control. In fact, some of the most important breakthroughs in agricultural technology (hybrid seeds) led to dramatic increases in yields at very low costs.

While the rate of growth of grain production averaged about 3% for the world, as well as for developed and developing countries as a whole, it has lagged in some countries (Bangladesh). In India grain production has levelled off during the past few years (is parallel with fertilizer use) so that grain imports became necessary on an increasing scale to maintain food supplies per capita. It is also important to keep in mind that the narrow margin between food production and population growth has permitted only a very slow improvement in the inadequate diets of some of the densely populated developing countries. Indeed there is evidence that the annual improvement in per capita food production in these countries was not always sufficient to meet the increase in effective demand resulting from rising incomes. Such imbalances are generally reflected in rising food prices, rationing, growing food imports, or a combination of these.

Table 2

Annual Rate of Growth of Grain Yields [a/]

	1950-1973	1963-1973
U.S.	3.8	3.6
Canada	1.3	2.3
EC-9	3.1	3.3
Japan	2.1	2.6
USSR	3.1	6.2 [b/]
Poland	3.0	4.2
Argentina	2.3	2.2
Brazil	0.2	0.4
India	2.5	2.5
Pakistan		4.3
Bangladesh		-0.5

a/ Average of first three years to average of last three years.

b/ 1963-65 base reduced by two drought years.

Projections

Long-term forecasts of food demand and supply are notoriously hazardous. Demand projections must take account of such factors as population and income growth, income distribution and urbanization, food prices, etc. Supply projections must assess the effects of rising demand for food on food production and the costs of production. This involves an assessment of the possibilities and costs of increasing yields by applying more water, fertilizer, pesticides, improved seeds, and improved cultivating practices; the possibilities and costs of bringing additional land into cultivation; the effects of government policies affecting agricultural production, product and input prices, credits, investments, education and research, land tenure and ownership. Supply and demand projections are both subject to great uncertainties, resulting in a wide range of possible surpluses or deficits which are subject to even wider margins of error than the underlying estimates of supply and demand.

One might think that the formidable array of factors and relationships involved, and the uncertainties attached to each, would be sufficient to give pause to anyone tempted to forecast for more than a few years ahead. Yet long-term projections have been made -- increasingly in the context of complete econometric models -- and will continue to be made.

In what follows we shall review briefly (a) the track record of some past attempts to forecast food demand and supply and (b) recent projections by FAO, the Economic Research Service of the U.S. Department of Agriculture and others.

Past projections have, in general, tended to underestimate both population growth and food production. Thus the Paley Commission,[1/] projecting

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1/ President's Materials Policy Commission, Resources for Freedom, 1952, Vol. V, Report 7 (submitted by John D. Black and Arthur Maass).

from 1950 to 1975, anticipated a 28% increase in the U.S. population, to 193 million; the actual population growth turned out to be 41%, to 219 million. Although the Commission underestimated the rise in real disposable income per capita, it was right in projecting only a modest increase (11%) in food consumption per capita in the United States. The Commission failed to anticipate the dramatic expansion of world demand for American grains and soybeans. On the supply side, the actual growth in output and yields generally exceeded the upper end of the range projected by the Commission (Table 3).

Rogers and Barton,[1/] who had the benefit of postwar experience up to 1960, still fell considerably short in projecting 1975 grain yields in the U.S., particularly of corn, which they put at only 61 bushels per acre, as compared with the current average yield of close to 100 bushels.

The current generation of projectionists [2/] is more circumspect

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1/ Rogers, R. O. and Barton, Glen T., Our Farm Production Potential, 1975. USDA, 1960.

2/ Notably the following:
FAO: Agricultural Commodity Projections, 1970-1980, Rome, 1971 (Single scenario).

FAO: Assessment of the World Food Situation, Present and Future, Rome, 1974.

U.S. Department of Agriculture, Economic Research Service, World Trade Models:
(a) World Demand Prospects for Grain in 1980, Dec. 1971.
(b) The World Food Situation and Prospects to 1985, Chapter 4, Projected World Food Supply and Demand, Dec. 1974.
(c) Alternative Futures for World Food, Working Materials, August 1975.

Iowa State University:
Blakeslee, Heady and Frammingham, World Food Production, Demand and Trade, Iowa State University Press, 1973.

Resources for the Future:
A. B. Carr and David W. Culver, Agriculture, Population and the Environment, in Commission on Population Growth and the American Future, Volume 3, 1972.

Table 3

Paley Commission Projections [a]
(1975 as % of 1950)

	Projection	Actual
Population	128	141
Real disposable income per capita	154	171
Food consumption per capita	111	113
Total food consumption	141	159
Production[b]		
All crops[c]	131-168	160
Wheat	120-150	190
Corn	140-200	176
Soybeans	120-150	500
Yields per acre[b]		
Wheat	120-150	200
Corn	140-200	220
Soybeans	120-150	125
Export volume		
Wheat and flour	53	410
Oilseeds and products	57	9000

a/ President's Materials Policy Commission, Resources for Freedom, 1952, Vol. V, Report 7 (submitted by J. D. Black and A. Maass).

b/ Upper Limit: Assuming "full, efficient and economic application of available technology," Lower limit: Yield "likely to be expected on the basis of past experience."

c/ Weighted average of food and feed crops.

in that they generally refuse to commit themselves to any single projection based on a single set of assumptions. Typically, current projections are cast in the form of alternative scenarios based on alternative assumptions as to population growth; income growth; production, price and trade policies; environmental policy constraints; etc.

The analytical techniques have also become more sophisticated. While the FAO studies are essentially projections of the "gap" between demand (estimated on the basis of alternative assumptions as to population and income growth) and supply (based on extrapolations of past growth rates), other studies have attempted to take account of the interactions between supply and demand via price, increasingly by means of econometric models involving interrelated demand and supply functions involving price as a variable. Such studies are, however, handicapped by the uncertain state of our empirical knowledge of long-term supply and demand elasticities, input-output coefficients, etc.

Table 4 compares the annual growth rates for population, income and demand for grains (for all uses) shown in the two latest studies by FAO and the U.S. Department of Agriculture, two earlier studies (1971) by the same organizations, and actual growth rates observed during the period 1961-1970.

As can be seen, the forecasts of population and income growth are remarkably consistent. Both organizations have raised their sights, in their most recent studies, as to the probable economic growth of developing countries. There is less agreement as to what this will mean in terms of demand for cereals.

The fact that the implied income elasticities are all lower than those derived from past experience might be considered consistent with Engel's law and the expectation of further gains in efficiency of conversion of grain

Table 4

Projections of Grain Demand by FAO and USDA/ERS

(Comparison of Annual Growth Rates)

DC's

	61-70	FAO 71	ERS 71	FAO 74[a/]	ERS 75
Population	1.1	1.0	1.0	0.9	0.8
GNP	4.4	5.2	4.3	4.5	4.0
Grain demand	2.5	2.0	2.0	1.7	1.9
Per cap. demand	1.5	1.0	1.0	0.8	1.1
Per cap. GNP	3.3	4.2	3.3	3.6	3.2
Implied elasticity	0.45	0.24	0.30	0.22	0.34

LDC's

	61-70	FAO 71	ERS 71	FAO 74	ERS 75
Population	2.6	2.7	2.6	2.7	2.7
GNP	4.6	5.4	4.7	6.4[b/]	6.0
Grain demand	3.7	3.2	3.3	3.3	3.2
Per cap. demand	1.1	0.5	0.7	0.6	0.5
Per cap. GNP	2.0	2.7	2.1	3.7	3.3
Implied elasticity	0.55	0.17	0.33	0.16	0.15

Table 4 (cont.)

	USSR and EE				
	61-70	FAO 71	ERS 71	FAO 74	ERS 75[c]
Population	1.3	1.7	1.2	--	1.3
GNP	6.5	5.8	5.5	--	5.3
Grain demand	4.3	2.1	1.8	--	2.3
Per cap. demand	3.0	0.4	0.6	--	1.0
Per cap. GNP	5.2	4.1	4.3	--	4.0
Implied elasticity	0.58	0.10	0.14	--	0.25

Sources: 1961-70: USDA/ERS, The World Food Situation and Prospects to 1985, Dec. 1974, Table 8. (1960/62-1969/71)

FAO 1971: Agricultural Commodity Projections, 1970-1980.

ERS 1971: USDA/ERS, World Demand Prospects for Grain in 1980, Dec. 1971 (Base period 1964/66).

FAO 1974: Assessment of the World Food Situation, Present and Future, Nov. 1974.

ERS 1975: Projections to 1985, Alt. 1, Working Materials, August 1975.

Footnotes: a/ Includes USSR and Eastern Europe.

b/ "Trend growth" assumption, including oil-exporting countries (5.7 oil exporters are excluded).

c/ Including PRC.

into livestock products; but can we really expect them to drop so sharply? One might expect income elasticities of total grain demand to be high at the lowest income levels (as in South Asia), lower in developing countries emerging from poverty but still on a largely vegetarian diet, lowest perhaps in newly affluent countries such as Japan (because of the lag in dietary habits), then rising again as the growing demand for animal products is reflected in increased use of grain for livestock feeding, and finally, declining as the consumption of livestock products approaches the saturation point. One would also expect this relationship to be affected by other factors such as the price and availability of grain, the availability of pasture and other non-grain fodder, the availability and price of foods not based on grain and of consumer goods other than food, and by differences in dietary responses to rising incomes (some relatively poor countries in Latin America have a strong preference for animal products as incomes rise). Finally, there are serious questions concerning the reliability of the data (on both grain consumption and incomes) and the comparability of the per capita incomes converted at official exchange rates. Factors like these may account for the poor correlation between income elasticities of grain demand and average per capita incomes evident in Chart 3.

In view of these uncertainties, it may be idle to add yet another global projection of world grain demand to those already existing -- particularly one that is not based on a careful analysis of the demand for specific foodstuffs and of grain requirements for different uses that follow from it. The main justification for doing so is that the assumptions and results would seem to be no less plausible than those implied elsewhere (Table 5).

Table 6 compares the resulting projections of total grain demand to

Table 5

Projections of World Grain Demand

			DC's[a]	LDC's	ACP[b]	World
1970	Population	Millions	1072	1755	794	3621
	Income per cap.	1970 $	3100	310	176	
	Elasticity	1960-70	0.45	0.55	0.58	
	Grain cons. per cap.[c]	Kgs.	577	220	257	333
	Total grain cons.[c]	Mill M.T.	617	386	204	1207
1985	Population	Growth rate (%)	0.9	2.7	1.6	1.9
		Millions	1222	2615	1008	4816
	Income per cap.	Growth rate (%)	3.5	3.0	2.0	
		1970 $	5208	485	238	
	Elasticity	1970-85	0.40	0.50	0.50	
	Grain cons. per cap.[c]	Kgs.	710	275	300	392
	Total grain cons.[c]	Mill M.T.	870	720	304	1894
		Growth rate (%)	2.3	4.3	2.7	3.0
2000	Population	Growth rate (%)	0.8	2.5	1.2	1.9
		Millions	1381	3792	1210	6383
	Income per cap.	Growth rate (%)	3.0	3.5	2.5	
		1970 $	8100	810	345	
	Elasticity	1970-85	0.25	0.45	0.45	
	Grain cons. per cap.[c]	Kgs.	810	350	355	450
	Total grain cons.[c]	Mill M.T.	1120	1325	430	2875
		Growth rate (%)	1.6	4.2	2.4	2.8

a/ Including USSR and EE.
b/ Asian centrally planned economies.
c/ Rice included on paddy basis.

Table 6

Comparison of Projections of World Grain Demand, 1985 and 2000

(Mill. M. T.)

	1970	1985			1990	2000
		Table 5	FAO[d/]	ERS I[a/]	FAO[d/]	Table 5
DC's[a/]	617	870	796	890	847	1120
LDC's[b/]	386	720	629	620	738	1325
ACP's[c/]	204	304	300	260	326	430
World	1207	1894	1725	1770	1911	2875

a/ Includes USSR and EE.

b/ Market economies

c/ Asian centrally planned economies.

d/ FAO Assessment, 1974.

e/ USDA/ERS, The World Food Situation and Prospects to 1985, Table 16, Alternative I. Adjusted for difference in 1970 base due to (a) inclusion of rice on milled basis, (b) omission of North Korea and North Vietnam in ERS studies.

1985 with those derived from other studies. It may be somewhat reassuring that the differences between the extremes of the range are of the order of 10-15 percent or less.

Supply projections are beset with even greater conceptual and statistical difficulties than demand projections. The FAO Assessment merely extrapolates production trends observed in 1961-1973 and finds, on this basis, that the resulting supply-demand deficit of the developing countries can be met by the projected surplus of the developed countries. Most studies have, indeed, assumed, on the basis of past experience, that the increase in demand can be met through increases in yields per acre, and/or increases in acreage, and/or double cropping, without significant increases in costs. In effect, this implies perfect elasticity of supply, over the long term, for the anticipated range of demand increases. Other studies (Paley Commission, Resources for the Future) have made rough allowances for increases in costs that may be expected to result from a speeding up of the historical rate of growth of production (and in the case of RFF, from environmental policy constraints on the use of certain inputs). The ERS model specifies area and yield elasticities for crops (as well as supply elasticities for livestock products) and finds that grain exporting countries will be able to meet prospective demands for grain and oil meal in 1985 without significant increases in real costs, except under the high demand alternative when costs are estimated to rise by 25-30% over the 1970 base. (The RFF study comes to a similar conclusion for the year 2000).

How useful are these projections? Skeptics can point out that the results depend heavily on the assumptions concerning the future growth of population, income and productivity. To the extent that the demand and supply elasticities and input-output functions used in the projections are derived from empirical observations, they are based on scanty and questionable data. Important institutional and policy variables tend to be ignored because they do not lend themselves readily to quantitative analysis. Considerations like these have led a panel of the U.S. National Academy of Sciences to conclude: "While models and mathematics may be helpful in making explicit implications of various assumptions, they cannot reduce the uncertainty of the future. Moreover, they may deceive the unwary, who often assume that specific numbers are somehow more accurate than verbal descriptions." 1/ This judgment may be too sweeping but it certainly has some validity.

Limits to Growth

There are nevertheless, some general conclusions that can be drawn:

1. With world population virtually certain to increase from 4 billion at present to over 6 billion by the turn of the century, the effective world demand for grains may be expected to double, from 1400 million tons in 1975 to 2800 million tons in 2000.

2. Past rates of production growth would be sufficient to meet this growth in demand.

3. There are no physical limits that would prevent a doubling of world food production. Indeed, world food production could be raised to at least four times its present level by applying the best technology presently

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1/ National Academy of Sciences, Agricultural Production Efficiency, 1975, p. 184.

known. This conclusion is based on the following considerations:

(a) There is ample room for further increases in yields per acre. In the industrial countries, average yields fall far short of those achieved by the most efficient producers, let alone those in experiment stations, and the use of fertilizers is still rising. In the developing countries, possibilities of improving yields are even greater. Average grain yields in these countries are less than half those in the industrial countries. Fertilizer and pesticide use are less than one-fifth that in the U.S., less than one-tenth that in Western Europe and one-twentieth that in Japan.

(b) Studies by the President's Science Advisory Committee (1967), Iowa State University, the U.S. Department of Agriculture and FAO all indicate that at least twice as much land as is now being used is suitable for crop production. The potential for expanding crop acreage is particularly great in Latin America where it could be quadrupled. Furthermore, in many areas blessed with a warm climate and an adequate water supply, there are substantial possibilities for increasing multiple cropping. 1/

(c) Only a small fraction of the annual supply of water is used in crop production. (Even in South Asia, less than one-third of the "economically useable" water is being used in crop production, and that is used inefficiently.)

4. As mentioned earlier, this conclusion does not allow for the probability of continuing advances in plant breeding, pest control technology, irrigation techniques, water desalination, and the development of foodstuffs and particularly livestock feeds from presently unutilized organic materials

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1/ Thus the Panel on World Food Supply of the President's Science Advisory Committee estimated the maximum gross-cropped area at 16.3 billion acres, as compared with 7.88 billion acres potentially arable land, and 3.43 billion acres actually harvested. PSAC, The World Food Problem, Vol. 2, p. 434.

derived from land or ocean resources. 1/ There is no reason to believe that agricultural technology has reached the end of the road.

5. While the world is far from "running out of" land, water, and energy, there are some areas which are considerably closer to the physical limits of exploitation of their agricultural resources (Japan, China).

6. In most developing countries, the major limiting factors on the rate of growth of agricultural production are economic, political, and institutional rather than physical.

7. For all practical purposes, the problem of future food supplies comes down to a question of costs. What will be the effects on unit costs of production of bringing in additional acreage, of better water control and additional irrigation? The investment requirements may seem staggering but one must keep in mind that these are permanent improvements which can be amortized over long periods of time. Current operating costs per unit of output may increase with increasing applications of fertilizer and pesticides, and it is possible (though not certain) that the world may be faced with a permanent increase in energy costs; but these factors may continue to be offset by the cost-saving effects of new technologies.

8. The econometric models have been useful in spelling out the mathematical consequences of alternative assumptions. For example, the USDA/ERS projections under Alternative IV indicate that if fertilizer and associated inputs were increased by 1 to 1 1/2 percentage points per year

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1/ Thus Walter H. Pawley estimates that 36 billion people could be fed 100 years from now, assuming two major technical breakthroughs: the development of economic methods of desalination of sea water and the development of methods to deal with tropical soils ("In the Year 2070," <u>Ceres</u>, July-August 1971).

above the trend rates of growth observed in 1960-72 (about 8%), it would enable the developing countries as a group to avoid any significant dependence on food imports. But thus far at least, they have not contributed much to the analysis of the economic, political and institutional impediments to the growth of agricultural production, or thrown much light on the effects on production costs of increased demand for food.

The Brookings Project

The Brookings project will concentrate on an intensive study of the physical, technological, economic, and institutional factors affecting grain demand and supply 1/ in nine countries or areas 2/ that account for the bulk of world agricultural trade. The emphasis will be on the search for factors that have been operative in the past, and that are likely to be most relevant in the future, in spurring or impeding production.

The factors determining demand will include population, income, urbanization, income distribution, price policy and rationing, feeding programs for disadvantaged groups and other factors affecting the patterns of grain utilization.

The factors determining supply will include land, fertilizer use, pesticides, irrigation, genetic improvements (HYV's), cropping patterns (including multiple cropping), price incentives (input and product prices), credit availability, agricultural investment policy, land ownership and tenure policy. Particular attention will be given to the costs of bringing additional

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1/ The focus on grains is justified by the fact that cereals are the principal food in the larger part of the world, and the principal raw material for food production in the developed countries. Moreover, the demand for grain may be a better index of the pressure on natural resources (land, water) than the demand for "food."

2/ U.S., Canada, Australia, Western Europe (EC-9), Japan, USSR and Eastern Europe, South Asia (India, Pakistan, Bangladesh), Argentina and Brazil.

acreage into production, the costs of raising yields per acre, and the possibilities of multiple cropping.

The study does not aim at constructing a complete econometric model. Its main objective is to assess the major elements that should enter into such a model. To the extent that the data permit, however, use will be made of multiple regression analysis and other quantitative techniques to project demand and supply on the basis of past relationships and judgments concerning future trends in the factors affecting demand and supply.

The judgments will be made on the bais of three alternative world scenarios:

A. Continuation of present policies (base model)

B. Freer international trade and capital flows (free trade model)

C. More restricted trade and capital flows (self-sufficiency model).

The study will then address the internal and external adjustment mechanisms through which the projected supply/demand gaps can be closed (or financed), including

(a) the price mechanism;

(b) national policies of supply and demand management that may reinforce or mitigate the effects of the market;

(c) international trade and aid policies that may help to narrow (or finance) projected demand/supply imbalances.

It is hoped that the country-by-country analysis of a wide range of factors affecting demand and supply will provide a more realistic understanding of the "trends behind the trends" and of the changes that could take place in the future. We believe it is the approach most likely to capture the effects of policy variables.

An important focus of the study will be the possible impact of increased trade and aid in facilitating national adjustments and thus lessening pressures for policies that may be costly in terms of economic welfare and growth.

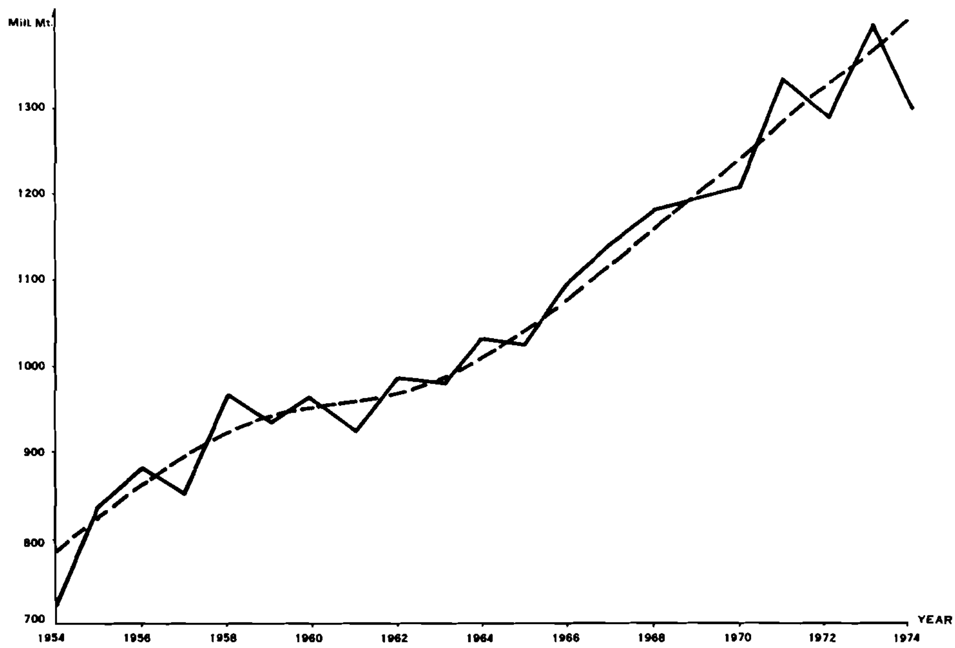

Chart 1. World Grain Production (incl. rice).

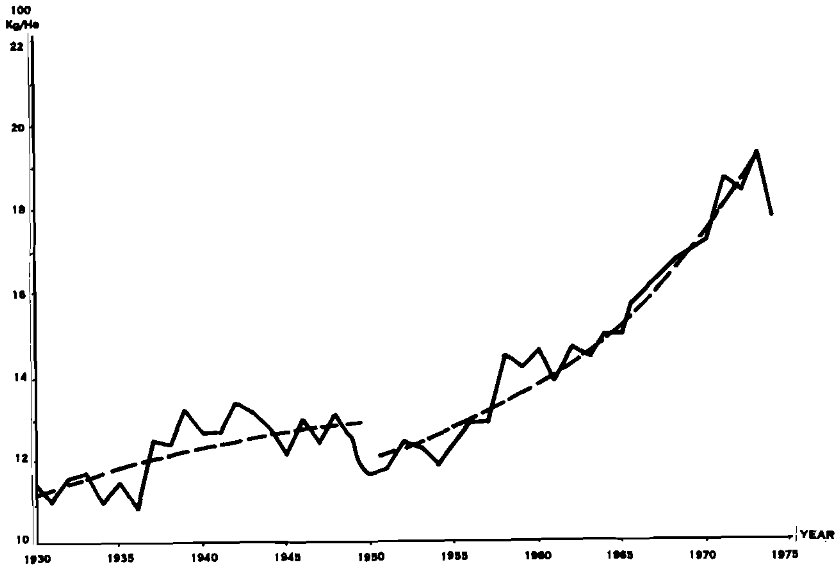

Chart 2. World Grain Yields.

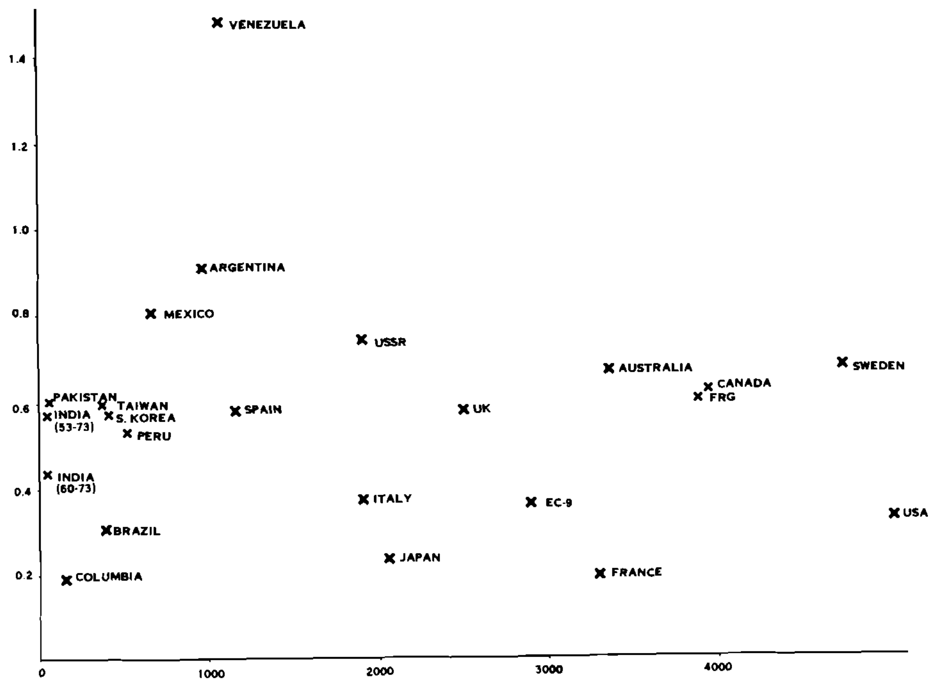

Chart 3. Implied Income elasticity of demand for grain (based on 1960-1973, Av. 66-68 in 1972$ GNP per capita).

Discussion

At the beginning of the discussion, Meadows raised a general question, why did papers tend to fall into one of two categories; one category assumes that things will become worse, and the other assumes that things will become better. She wondered whether a meta-model or an experiment could be designed to look at a new kind of data in such a way that would decide who is right; it would make a big difference whether one considers the situation such that the market mechanism will be able to take care of it, or whether one sees the situation in such a way that an international monetary reordering is essential, or whether one thinks that the situation is such that no major action needs to be taken. Policy implications differ enormously; in part this may be determined by whether one thinks primarily in physical or in monetary terms. Furthermore, time lags are also viewed differently. Lastly specialists in the agricultural field may overlook the difficulty of bringing in sufficient resources of energy, capital investments, and many other things from other sectors. Bruckmann added that, in general, the less variables are involved in a model, the more "optimistic" the model tends to be, overlooking constraints coming from variables that have been exogenized. The more one includes ecological and other non-economic variables, as well as time horizon, time lags, and the like, the less one comes up with optimistic views. Some overly optimistic models reminded him of the attitude of someone owing ten people a thousand dollars each and of having a fair chance to make a thousand dollars; he goes to bed happy, convinced that he is able to pay back any single one of his debts if he earns a thousand dollars. However, he has not yet earned the thousand dollars. Also, if he did make this amount, he might spend it on things other than paying his debts. And, even if he makes the money and decides not to spend it on something else, and in fact pays back one of his debtors, all his other debts will remain.

Waelbroeck stressed the difficulty of answering the question raised by Meadows. The food situation is highly sensitive: a little more food and there are surpluses; a little less food and there are major difficulties and famines. It was a sobering experience for him to find out that all agricultural models have been constructed on little evidence. For example, it has been stated that it is impossible to raise agricultural production by an average of more than 4% in a number of consecutive years; however, it has just been stated that agricultural production in Pakistan increased 100% within ten years. So, where the data base on production figures is unclear, how much less can be expected from the data base on less documented variables? Apparently, there is a misallocation of prestige: too much prestige is attached to conclusions and none is attached to data bases, model assumption, and methodology.

Parikh stated that there is a certain relation between the scientific field and optimism: system dynamicists tend to be gloomy; linear programmers tend to be optimistic.

Rademaker expressed his surprise that so far at the conference pollution has received very little attention. If, by the increased use of fertilizers, pesticides and herbicides one can increase agricultural production, then by no means can pollution be overlooked. Levis replied that the U.S. Geological Survey is trying to determine the possible effects of the increased use of these production means on ground water; water may be a limiting resource, not so much in the sense of physical existence, but because of the way it is being used. It may be that water quality problems actually become a constraint. Swanson added that at hearings held in the U.S. about three years ago, there was a great deal of uncertainty about the impact of increased use of fertilizer. Because little is known, this aspect should not be neglected--from an agricultural point of view it *may be* a side effect, but certainly from a ecological view, *is* a major effect.

Gallopin added that, based on studies carried out in various countries, one may roughly conclude that the cost of pollution abatement might be in the magnitude of less than 2% of GNP. With this amount, pollution could be reduced to a level much below the present one. Thus the position of the model of Fundacion Bariloche was that pollution control is today technologically possible and within a reasonable order of magnitude of cost. Bruckmann pointed out that his remark about optimists versus pessimists referred not so much to the number of variables involved, but to the question to what extent the problem is seen in a systemic way: the more systemic the view, the more cautious one becomes. In this respect, the 2% figure just mentioned by Gallopin may serve as a perfect example. It may be true that 2% of the GNP might suffice to eliminate pollution, but this view alone does not explain the mechanisms needed to raise the 2% of the GNP or rather to divert these resources from other goals, (2% of GNP are many millions of local currency), also it does not indicate the likelihood of the occurrence of any of these actions. So this figure may be utterly misleading.

Sanderson encountered, in his opinion optimism or pessimism have nothing to do with the scope or the complexity of the model. It is mainly an issue between economists and non-economists: economists are congenitally optimistic, convinced that money can buy and fix everything. The economist has the added advantage of being able to point to the experiences of the past which shows that the technological advances have more than upset the declining returns of any given physical lump of natural resources. In the economists' view, pollution is dealt with in the same way: it is simply a social cost which the market mechanism unfortunately has not been able to handle. But it would take only a very small adjustment for the market mechanism to fix it. It is good that environmentalists have increased the concern for the environment to such an extent that something is now being done.

According to Batteke, the pendulum was swinging from the Meadows approach back to the economists'. Coming back to the question of pollution, he said that large amounts of money are being spend on pollution abatement. However, these costs have so far been applied more to pollution caused by industrial systems.

Kulikowski added that there is also the question of quality. For example: on a given amount of land, one can either raise a large amount of low quality wine or a smaller amount of high quality wine; what applies to wine is equally valid for many other products such as chicken. Swanson replied that sometimes the market mechanism reflects quality; the U.S. has recently undergone the experience of trying to change beef standards, which met with a good deal of opposition.

De Hoogh asked Sanderson about the future development of food prices, since scarcity of food is implicitly or perhaps explicitly contained in his projections. He expressed interest in the plan of the Brookings Institution to introduce policy alternatives in their forthcoming agricultural model.

What were the policy goals? Sanderson replied that in his opinion the purpose of any study is to understand what is happening, what is likely to happen and whether some well designed policies are able to smooth the way for adjustments which are more or less inevitable. As a modeler, he might find himself in the same situation as the Bourgois Gentilhomme, who was unaware of having spoken prose all his life. As to prices, one should distinguish between the very rough projections in Table 5, not taking into account prices, and a more detailed treatment of prices elsewhere. As regards the modeler's task, Roberts stated that he resented the idea of a moratorium on modeling, to be used to obtain ample evidence. This seems to be wrong for practical reasons: having spent a substantial amount of time on collecting data, one then begins the new modeling work, only to find out that the data were the wrong kind. Modeling work and the collection of data therefore must be an interactive process. Furthermore, the request that data be collected first is very often politically motivated in order to delay necessary decisions.

An Analysis of the World3 Agricultural Submodel†

W. Thissen

1. *INTRODUCTION*

Global modelling has gone through a process of fast growth during the past three years. After the publication of the first world models by Forrester and Meadows, it was generally felt that the issues brought up were of considerable interest, and that further study and analysis would be necessary. More precisely, it was considered desirable to analyse the processes described only roughly in World2 and World3 more profoundly, and therefore more detailed and more disaggregated models had to be constructed. Several modelling teams were set up, most of which are still actively engaged in the building of new, often high-dimensional global models. As a result, the number of models available or presently under construction is rising rapidly, and public attention is above all directed towards the latest results obtained from the newest and - often - most detailed model. Since in most of these studies the main emphasis was laid on the development of new models and the generation of simulation results, the analysis and evaluation of those models already available have more or less fallen into oblivion, although such evaluation forms an important part of the systems analysis approach. Especially if a model is constructed to be used as an aid to policy making, it is necessary to be able to understand the model and explain how its behaviour comes into being without reference to a computer. As the new models are growing larger and larger, it is becoming more and more difficult and more important to gain such an understanding.

For these and other reasons the Dutch "Global Dynamics" project group has paid much attention to this aspect of systems analysis. The main accent has been on the analysis of the world models by Forrester and Meadows, and in this context a number of methods for enhancing the comprehensibility of non-linear mathematical models have been tested and compared. The main results of the World2 and World3 studies have been described in a number of progress reports *(1)*.

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† The research presented in this paper was supported in part by the Netherlands Organisation for the Advancement of Pure Research Z.W.O.

This paper presents only part of the conclusions: it attempts to give an idea of the analysis of the agricultural sector of World3, and some of the results. The activities described are not yet in their final state, but full details will be published before long.

Finally, it should be observed that no attempts have been made to extend the World3 model or to criticise the validity of the assumptions. The submodel's equations have been studied in the form in which they are described in the technical report of the Meadows team *(2)*.

2. *A SHORT DESCRIPTION OF THE WORLD3 AGRICULTURAL SUBMODEL*

It is beyond the scope of this paper to describe the equations of the agricultural sector of World3 in full detail. Those interested are referred to the extensive report prepared by Meadows et al. *(2)*.

Figure 1 shows the DYNAMO-flow diagram of the sector's equations. It appears that the subsystem is influenced by three variables from other sectors: Industrial Output IO*, Population POP, and the Persistent Pollution ratio PPOLX. IOPC (Industrial Output Per Capita) is the quotient of IO and POP. In turn, the agricultural subsystem influences these three sectors by means of the variables FIOAA (Fraction of IO Allocated to Agriculture), FPC (Food Per Capita), and the persistent pollution generation from agricultural output. For ease of discussion, and because its influence on the model results is only weak, this last factor will further be left out of consideration.

The state variables PAL (Potentially Arable Land), AL (Arable Land), UIL (Urban-Industrial Land) and LFERT (Land Fertility) seem to play a central part. The rates of change of PAL, AL and UIL are controlled by the Land Development Rate LDR, the Land Removal for Urban-Industrial Use LRUI and the Land Erosion Rate LER. Land Fertility is influenced by PPOLX and by the Fraction of inputs Allocated to Land Maintenance FALM.

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* The explanation of the abbreviations used in the text is given in the Appendix.

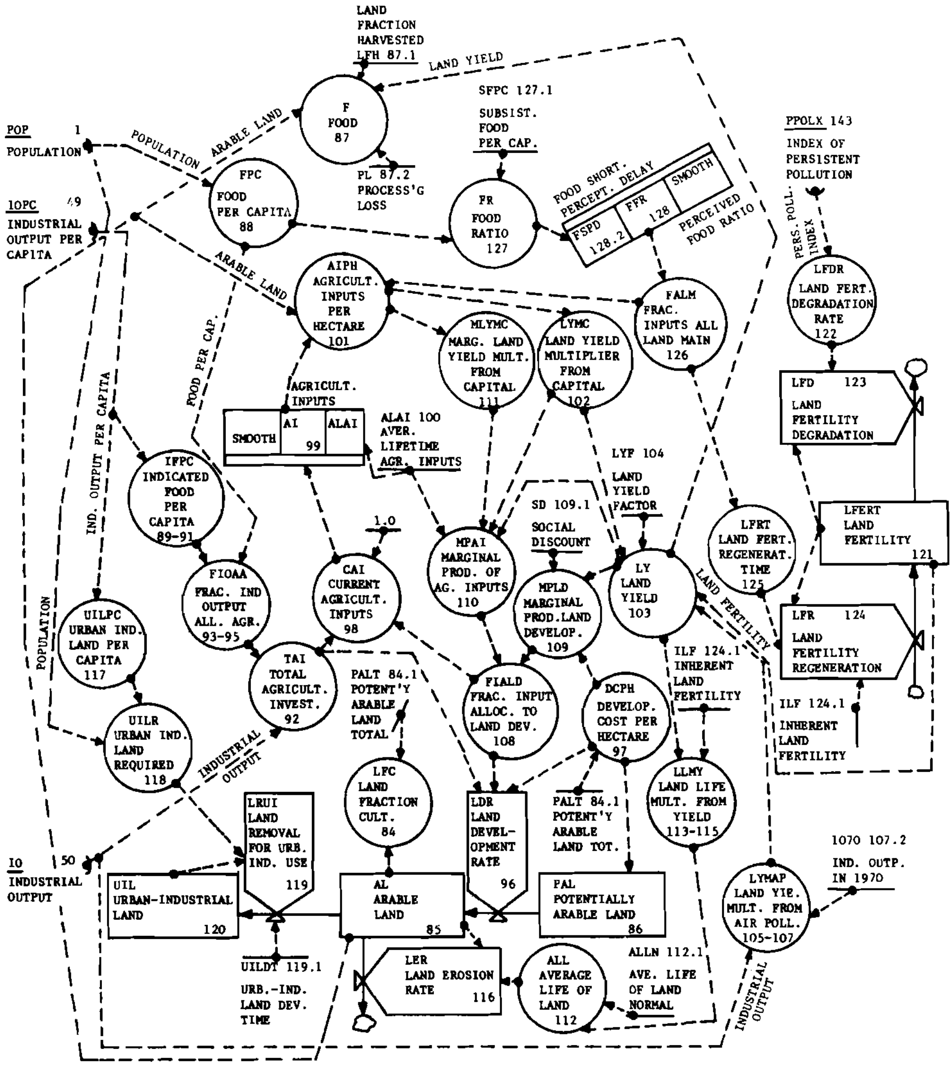


Figure 1: DYNAMO-flow diagram of the World3-agricultural sector (input variables are underlined).
Source: ref. (2).

The value of FIOAA is calculated as a function of the ratio between the actual values of FPC and IFPC (Indicated Food Per Capita). Subsequently, Total Agricultural Investments TAI are assigned to investments in land development (a fraction FIALD), investments allocated to land maintenance (FALM) and direct inputs used to increase the land yield (the remaining part).

The following discussion about the working of the equations of this sector applies to the so-called standard-run conditions. The standard or reference run is a model calculation, in which a number of coefficients are set to such values that the model's outcome agrees with what is known about reality in 1900 and 1970, which calculation is continued up to the year 2100. The behaviour of the model in the standard run is characterised by a period of growth followed by a rather sudden decline of variables like industrial output, food production, population, etc., setting in about 2030, and caused by depletion of non-renewable resources. Because of the restricted model validity, especially as far as the latter half of the 21st century is concerned, the main emphasis of this discussion will be on the behaviour between 1970 and, say, 2040.

3. *FIRST SIMPLIFICATIONS*

To obtain a better insight into what are the factors really important to the sector's outcome, the behaviour of all variables in a standard-run calculation was observed. It appeared that a number of variables have a fairly constant value throughout the whole run. It was found that these can be replaced by constants without considerably affecting the sector's overall behaviour. Other simplifications were obtained by putting the rates LER and LRUI equal to zero, because, owing to their low values compared to the values of the state variable they affect (AL), their impact on the model results is only slight. These observations have yielded the following list of simplifying assumptions:

1. LYMAP = 1.

This means that the influence of industrial production on land yield acting via air pollution (LYMAP = Land Yield Multiplier from Air Pollution) is omitted completely. In its original form, LYMAP would only differ from 1 if IO rose to ten times its 1970-value or higher. Such values are not attained in the standard-run calculation.

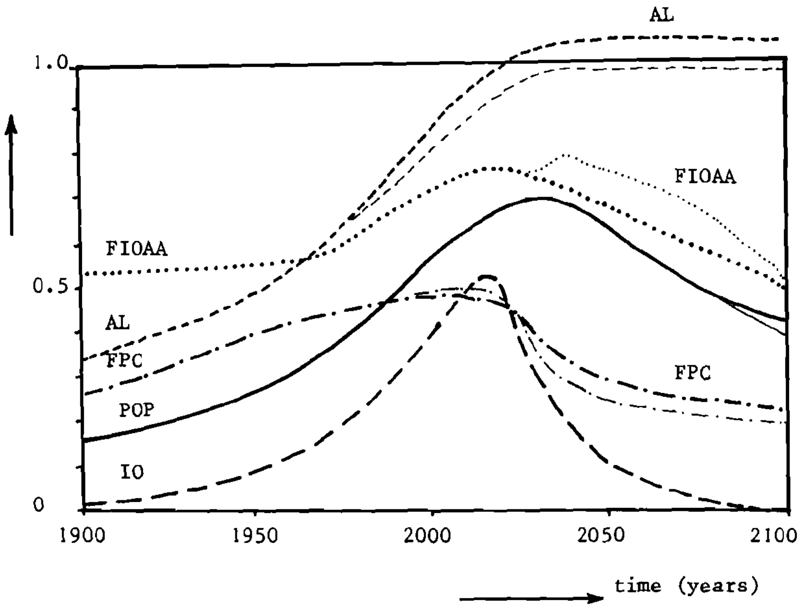
2. FALM = 0.06.
In the standard run the value of FALM varies between 0.04 and 0.07. One of the two influences of FALM acts via a factor (1-FALM), which factor varies between 0.96 and 0.93, and may be replaced by a constant. Furthermore, FALM influences the land fertility subsystem, but a test calculation has shown that replacement of FALM by a constant does only slightly affect the behaviour of the sector after 2020.
3. LER = 0.
Consideration of the standard-run behaviour of the Land Erosion Rate LER teaches us that the total amount of land eroded between 1900 and 2100 is not more than about 5% of the value of AL in 2100. Complete omission of land erosion does not have any significant effect for the submodel's standard-run behaviour.
4. LRUI = 0.
The same kind of considerations as above lead to the omission of the Land Removal for Urban-Industrial Use LRUI and hence of the complete urban-industrial land subsector.

Figure 2 shows the outcome of a run in which all of these four simplifications have been introduced. Only after 2040 can changes of minor importance, especially in the value of FIOAA, be perceived. Figure 3 represents the Dynamo flow diagram after introduction of the simplifications mentioned above. The picture is considerably clearer than Figure 1, especially owing to the omission of all variables related to urban-industrial land and land erosion.

4. *A FURTHER ANALYSIS OF THE NUCLEUS OF THE AGRICULTURAL SUBSYSTEM OF WORLD3*

For ease of discussion we will now divide the remaining sector-equations into four parts, each of which will be dealt with separately. The following subsectors will be distinguished:

- The land fertility subsystem, indicated by the thin solid lines in Figure 3.
- The equations describing the investment allocation decision between investments in direct inputs, and in land development (the calculation of FIALD; fat broken lines).
- The state-variables PAL and AL, and the equations directly related (thin broken lines).
- The remaining equations, in which food production and total investments



scale FIOAA : 0.20 | scale POP : 10^{10}
scale AL : $2.5\ 10^{9}$ | scale IO : $5\ 10^{12}$
scale FPC : 1000

Figure 2: Standard outcome after introduction of the simplifications mentioned in Section 3, page 5 (fat lines) compared with the standard results of the complete model (thin).

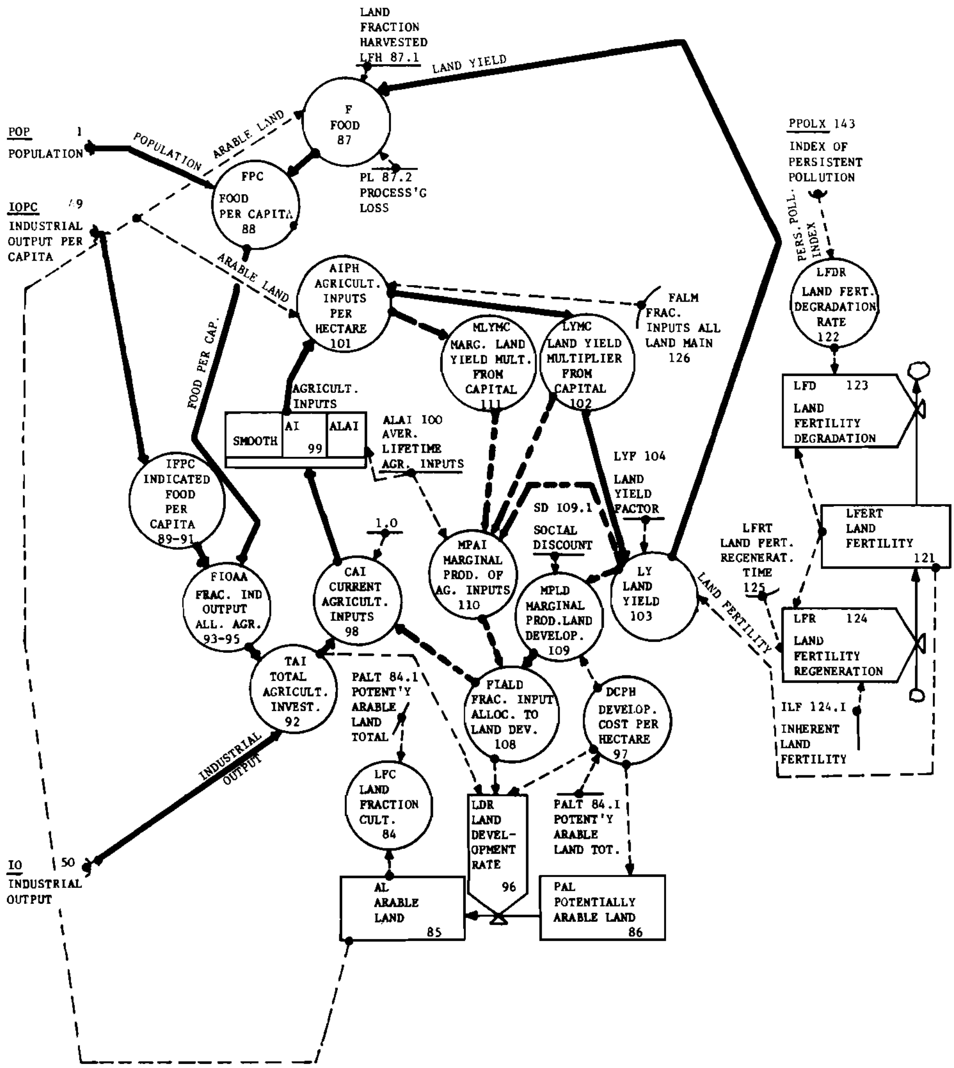


Figure 3 : DYNAMO-flow diagram after introduction of the simplifications mentioned on page 5.

in agriculture are calculated, and on which the input variables IO and POP act (fat solid lines).

4.1 The Land Fertility subsystem

Inspection of Figure 3 teaches us that, after the introduction of constant FALM, the land fertility subsystem has only one input variable (PPOLX), and one output (LFERT). Since only one level-equation appears in the subsystem, its behaviour is described by a first-order differential equation, which reads:

$$\dot{LFERT}^{*} = \frac{ILF - LFERT}{LFRT} - LFERT*LFDR \ . \qquad (1)$$

ILF and LFRT (due to constant FALM) are constants, and the value of LFDR is determined by PPOLX. By reordening the coefficients, (1) can be written in the standard form of a first-order transfer system:

$$\dot{LFERT} = -LFERT * \frac{1 + LFDR*LFRT}{LFRT} + \frac{ILF}{LFRT} \ . \qquad (2)$$

From (2) it follows for the time-constant τ of the system:

$$\tau = \frac{LFRT}{1 + LFDR*LFRT} \ , \qquad (3)$$

and for the static value of LFERT:

$$LFERT_{static} = \frac{ILF}{1 + LFDR*LFRT} \ . \qquad (4)$$

For standard-run and similar conditions the value of τ is less than 5 years, which is low in comparison with the time constants determining the overall model behaviour (these have values of 20 years and more). Consequently, it is suggested that the differential equation for LFERT (1) may be replaced by the algebraic equation (4) without affecting the model's behaviour. Test calculations have fully confirmed this hypothesis, and hence it may be concluded that the link between the persistent pollution subsystem and the agricultural subsystem, formed by LFERT, acts in a more or less algebraic way, i.e. without any delay or lag.

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* $\dot{x}$ means derivative of x with respect to time.

4.2 *The allocation of investments to land development (fat broken lines).*
The value of FIALD (Fraction of Inputs Allocated to Land Development) is calculated as a function of the ratio between the marginal productivity of direct agricultural inputs (fertiliser, pesticides) and the marginal productivity of development of new land. FIALD affects two other variables: on the one hand, its value influences CAI and hence AIPH via a factor (1-FIALD), on the other it influences the Land Development Rate LDR. In the standard run FIALD gradually increases from 0.15 to 0.25 between 1900 and 2000, drops from 0.25 to a very low value between 2000 and 2050, and is virtually nil thereafter. Owing to its influence via (1-FIALD), the effect of the variations of FIALD on AIPH is fairly weak.

Because FIALD acts as a multiplier in the investments in land development through the formula LDR = TAI*FIALD/DCPH, it was expected that its influence would be considerable. However, by means of a series of sensitivity tests it has been shown that LDR is not very sensitive to the exact value of FIALD and that FIALD might even be replaced by a constant without changing the behaviour of PAL and AL considerably. Apparently, the behaviour of LDR is mainly controlled by TAI and DCPH.

A more detailed analysis has been performed, but because this paper aims at covering the main lines and conclusions only, FIALD will be assumed a constant in the following discussion. Consequently, the sector's flow diagram can be further simplified (Figure 4). Figure 5 shows the outcome of a calculation in which the assumption FIALD = 0.19 was added to the simplifications discussed in section 3. It shows that the behaviour of the output variables FIOAA and FPC is hardly affected.

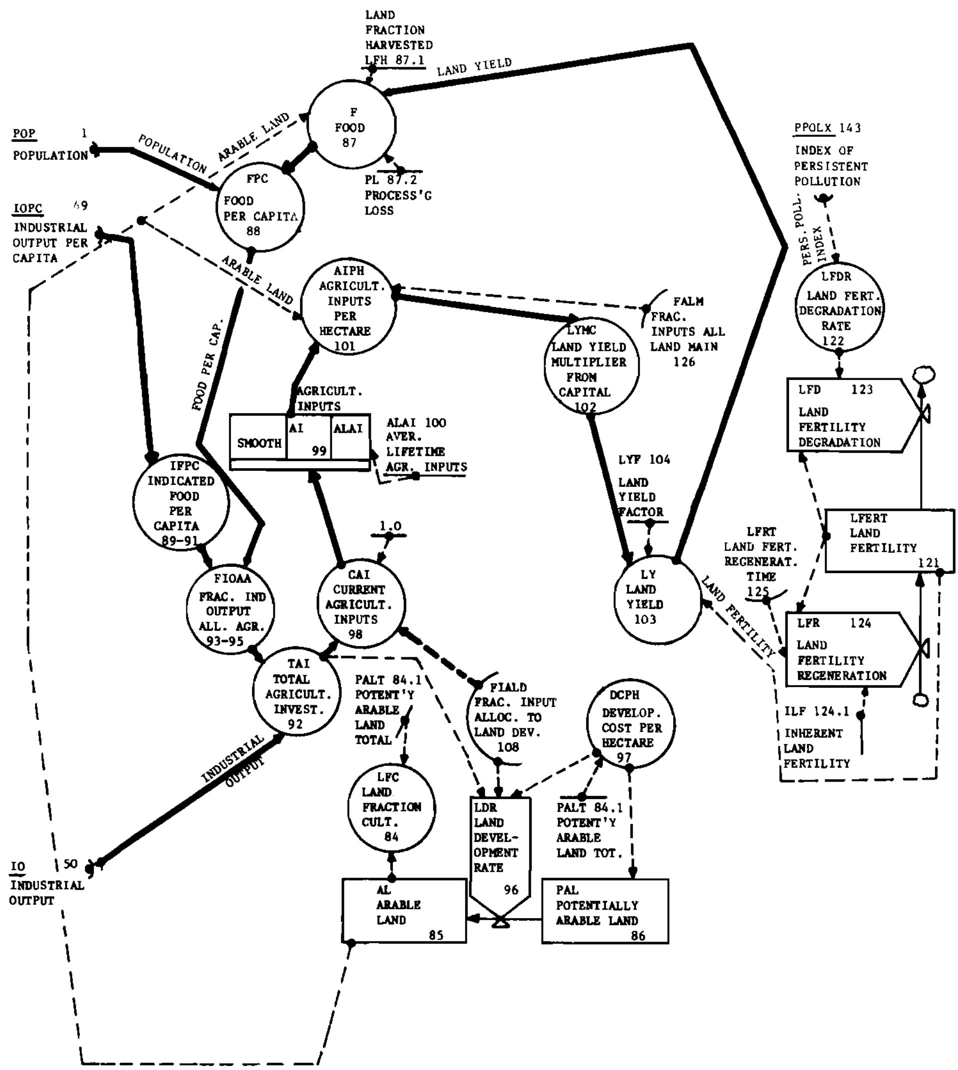


Figure 4 : DYNAMO-flow diagram after introduction of constant FIALD, together with the former simplifications.

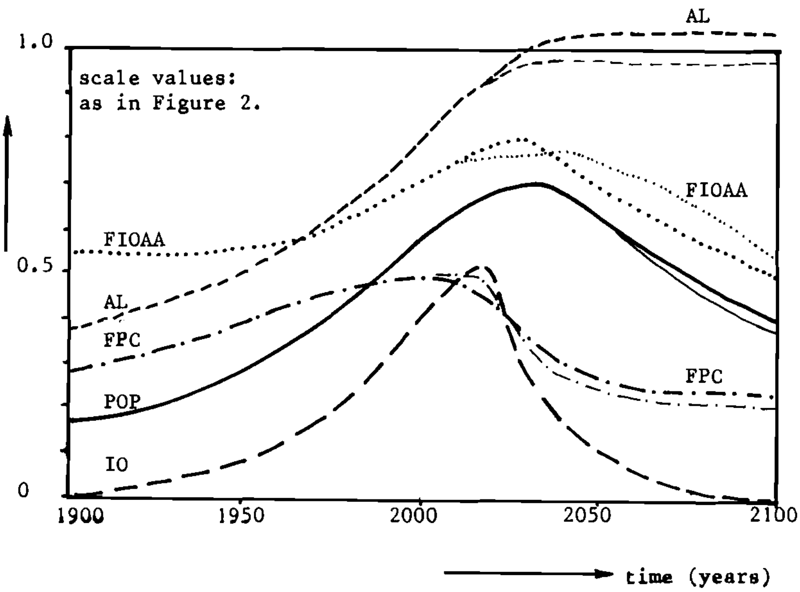


Figure 5 : Standard outcome after additional introduction of FIALD=0.19. Thin lines: original standard run.

4.3 *Arable Land and Potentially Arable Land*

If the effects of land erosion and land removal for urban-industrial use are neglected (LER = LRUI = 0), the rates of change of AL and PAL are equal, but with opposite signs:

$$\dot{AL} = LDR = -\dot{PAL} \quad . \tag{5}$$

Integration of (5) yields:

$$AL(t) - AL(1900) = \int_{1900}^{t} LDR(\tau)d\tau = PAL(1900) - PAL(t) \; . \tag{6}$$

Hence, if either of the state variables PAL and AL is known, the other can be calculated directly, because

$$PAL(t) = PAL(1900) + AL(1900) - AL(t) \; . \tag{7}$$

AL will be chosen as a key variable and henceforth variables that previously were functions of PAL, will be considered functions of AL.

As will be clear from Figure 4, the only variable influencing AL from outside the land-subsystem is TAI, since FIALD is considered constant and DCPH is a function of AL itself (via PAL!). The development costs per hectare are assumed to increase more or less exponentially as the area of potentially arable land decreases. A good approximation for the table function DCPH is

$$DCPH = a.\exp(-b.PAL) \quad . \tag{8}$$

where a and b are constants.

Substitution of (7) and (8) in the formula

$$LDR = FIALD*TAI/DCPH, \tag{9}$$

and subsequent integration according to (5) yields the expression

$$AL(t) = p.\ln\{q \, . \int_{1900}^{t} TAI(\tau)d\tau \; + r\} \quad , \tag{10}$$

with p, q and r constant. This formula reflects the diminishing returns of investments in land development.

4.4 *The calculation of the important input and output variables*

Using the remaining equations (fat solid lines in Figure 4), the output variables FPC and FIOAA are calculated. The equations form a loop, in which the only dynamic element is the smooth-function AI. The time-constant of this first-order lag is equal to 2 years and hence its value is small in comparison to the predominant time constants in the other sectors. However, if DYNAMO is used as simulation language, the inclusion of such a dynamic element is necessary, because algebraically closed loops have to be avoided. But for purposes of structural analysis, or if a stable iteration procedure can be included (as in Algol), the smooth function AI can be completely omitted. Test calculations have, indeed, shown that omission of AI has hardly any effect. But if AI is omitted, the loop is closed algebraically, and hence FPC, FIOAA, F, etc. can be considered algebraic functions of the input variables POP, IO, AL and LFERT. These functions are given implicitly by the equations of the loop, and can only be made explicit by means of (numerical) solution of the implicit equations.

However, the concept of an algebraic relation alone is sufficient to enable important structural conclusions to be drawn: the working of the sector's nucleus can now be sketched as in Figure 6 below. The figure shows that two important components determine the characteristic behaviour: First, the algebraic system relating output and input variables, and, secondly, the dynamic transfer system relating AL to TAI. The LFERT subsystem is incorporated in the central box, and hence PPOLX is considered an input variable.

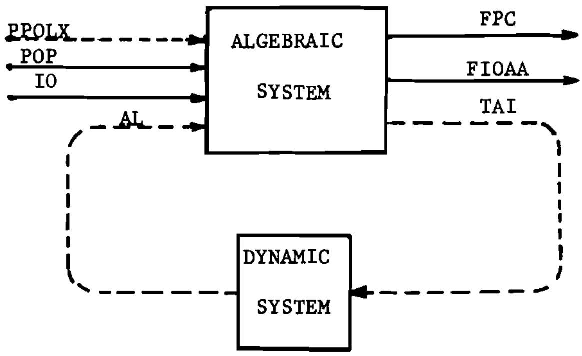
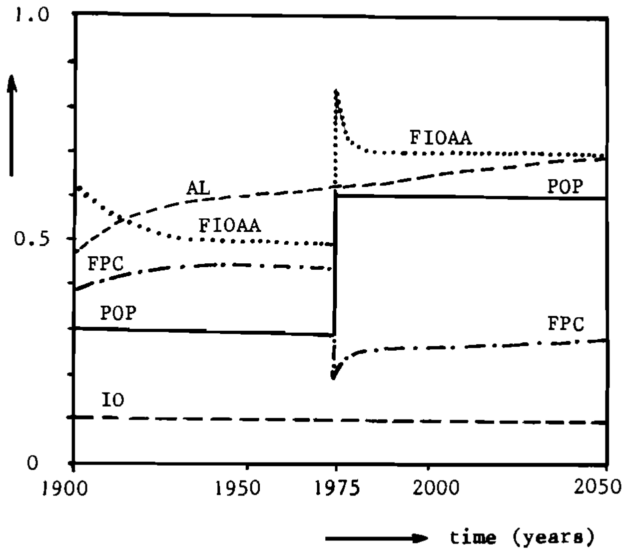


Figure 6 : The working of the most important part of the World3 agricultural sector (broken lines indicate weaker influences).

To obtain some idea of the relative importance of each of the input variables, a sensitivity analysis of the algebraic system was performed for a number of standard-run situations. It was found that mainly POP and IO are determining the behaviour of the output-variables, and that the influence of PPOLX is weak. The values of FPC and FIOAA are only moderately sensitive to the value of AL. This leads us to the conclusion that the agricultural sector *as a whole* acts in a more or less algebraic way. This means that the values of the output variables are almost immediately adapted to variations in the inputs, without any delay or lag.
This hypothesis can easily be tested in the following manner: First, the values of the input variables POP and IO are frozen, and FIOAA and FPC are more or less constant. Then, a step-function is imposed on POP, IO or both, and only shortly thereafter FIOAA and FPC will reach their new equilibrium values.



scale values: as in Figure 2.

Figure 7: Behaviour of a number of variables of the agricultural sector, if a step function is imposed on POP in 1970.

In Figure 7, the result of such a test calculation with the complete sector model is given. The value of POP is augmented suddenly in 1975. Within a few years, the new equilibrium values of FIOAA and FPC are attained and the result fully confirms the hypothesis of an almost algebraically functioning agricultural sector. Moreover, the figure shows that the slow changes in the value of AL do not affect the value of FIOAA and FPC appreciably.

A further analysis was performed to get a better insight into the effect of variations of IO and POP in the 1975 situation. It was found that variations in IO hardly affect the value of FIOAA, but stimulate FPC. Changes in POP affect both output variables, but total food production F remains fairly unchanged. This analysis is being continued, and we hope a more extensive, final report will be available in a few months.

5. *CONCLUSIONS AND FINAL REMARKS*

It has been shown that by application of fairly simple techniques much insight into the behaviour of a complex-looking set of mathematical equations can be gained. A large part of the equations constituting the World3 agricultural subsystem has no significant influence on the model results, at least under standard-run and similar conditions. The basic properties of the remaining part were found to be quite simple: the sector acts as an almost lag-free link between the population subsystem and the capital and resources subsystem. Except for AL and PAL, the state variables exert no important dynamic influences. The equations for urban-industrial land can be omitted completely, and the land fertility subsystem can be replaced by an algebraic equation. Furthermore, PAL and AL can be combined into one state variable, which variable appears to have an only moderately important influence on the sector's behaviour. Except for abnormal runs in which a pollution explosion occurs, the influence of PPOLX is weak, and hence it is concluded that the food situation in World3, expressed by the variable FPC, is mainly determined by the behaviour of the variables IO (Industrial Output) and POP (Population). In the standard run, the decline in IO, caused by depletion of non-renewable resources and setting in about 2030, enforces a decline in food production and, consequently, in FPC.

This understanding of the sector's behaviour can be useful for different purposes. The insight gained permits of explaining why the model behaves the way it does. It is possible to predict what will be the sector's outcome if alternative assumptions, or different policies are introduced into the model, because its working is not counter-intuitive anymore. The knowledge that the main part of the sector behaves algebraically makes control studies of the model much easier, since the only dynamics that have to be taken into account originate from the equations determining AL and PAL. Furthermore, an important aim of dynamic modelling is to help to enlarge the understanding of the working of the real system, and a first step in that direction is the understanding of the model of that system.

Finally, one of the motives to write this paper was to stimulate further discussion. From the results of our study, a number of intriguing questions emerge, such as: Do other agricultural (sub)models also display such a simple set of basic properties, or are they *essentially* more complex?

Do they also contain a large number of "dummy" variables and relations? Do they also act as more or less algebraic systems? Or is their behaviour essentially different? And, if so, why?
We hope these and other questions will serve as guidelines and act as catalysts in further discussions.

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APPENDIX : List of abbreviations and their explanation

AI	:	AGRICULTURAL INPUTS (DOLLARS/YEAR)
AIPH	:	AGRICULTURAL INPUTS PER HECTARE (DOLLARS/ HECTARE-YEAR)
AL	:	ARABLE LAND
ALAI	:	AVERAGE LIFETIME OF AGRICULTURAL INPUTS (YEARS)
CAI	:	CURRENT AGRICULTURAL INPUTS (DOLLARS/YEAR)
DCPH	:	DEVELOPMENT COST PER HECTARE (DOLLARS/HECTARE)
F	:	FOOD(VEGETABLE-EQUIVALENT KILOGRAMS/YEAR)
FALM	:	FRACTION OF INPUTS ALLOCATED TO LAND MAINTENANCE (DIMENSIONLESS)
FIALD	:	FRACTION OF INPUTS ALLOCATED TO LAND DEVELOPMENT (DIMENSIONLESS)
FIOAA	:	FRACTION OF INDUSTRIAL OUTPUT ALLOCATED TO AGRICULTURE (DIMENSIONLESS)
FPC	:	FOOD PER CAPITA (VEGETABLE-EQUIVALENT KILOGRAMS/PERSON-YEAR)
IFPC	:	INDICATED FOOD PER CAPITA (VEGETABLE-EQUIVALENT KILOGRAMS/PERSON-YEAR)
ILF	:	INHERENT LAND FERTILITY (VEGETABLE-EQUIVALENT KILOGRAMS/HECTARE-YEAR)
IO	:	INDUSTRIAL OUTPUT (DOLLARS/YEAR)
IOPC	:	INDUSTRIAL OUTPUT PER CAPITA (DOLLARS/PERSON-YEAR)
LDR	:	LAND DEVELOPMENT RATE (HECTARES/YEAR)
LER	:	LAND EROSION RATE (HECTARES/YEAR)
LFDR	:	LAND FERTILITY DEGRADATION RATE (1/YEAR)
LFERT	:	LAND FERTILITY (VEGETABLE-EQUIVALENT KILOGRAMS/HECTARE-YEAR)
LFRT	:	LAND FERTILITY REGENERATION TIME (YEARS)
LRUI	:	LAND REMOVAL FOR URBAN-INDUSTRIAL USE (HECTARES/YEAR)
LYMAP	:	LAND YIELD MULTIPLIER FROM AIR POLLUTION (DIMENSIONLESS)
PAL	:	POTENTIALLY ARABLE LAND (HECTARES)
POP	:	POPULATION (PERSONS)
PPOLX	:	INDEX OF PERSISTENT POLLUTION (DIMENSIONLESS)
TAI	:	TOTAL AGRICULTURAL INVESTMENT (DOLLARS/YEAR)
UIL	:	URBAN-INDUSTRIAL LAND (HECTARES)
τ	:	TIME CONSTANT

Discussion

Meadows stated that she agreed with Thissen's claim that much can be learned from investigating a simplified version of the major structure of a model. The standard run of the simplified version may not differ from that of the original model, the latent structure of the model remaining inactive. However, it is the other runs that deviate from the standard run where the latent structure becomes active; it is here that the behavior of a simplified version may differ from that of the full model. Since the comparison of the different runs was one of the main goals of the venture, this comparison could not have been arrived at equally well by limiting the model to the simplified version.

Thissen agreed that the simplified version can serve certain purposes and not others. Rademaker added that the construction of such a simplified model is on the order of magnitude of 1% of the original modeling effort. He therefore suggested that, as a rule, modelers consider this additional effort worthwhile. Roberts raised one question concerning the testing of individual variables by varying them and checking the results: if one has low sensitivity to a single variable, is it not possible to eliminate it from the test? There may be combinatorial effects by which individual variables have low sensitivity. Thissen replied that, to a certain extent this, too, can be checked better by a simplified version.

Kaya, when asked whether this procedure of simplified versions had been applied to optimization models, replied that, his group had not yet been able to find a method for simplifying optimization models. Their study was based on World II and World III and they were the only well-documented and available models at the time the project was begun.

Panel Discussion

(Chairman: Ferenc Rabar)

Cole opened the discussion: I would like to bring together some of the ideas expressed so far. We have discussed several models which in many ways are similar and in many other ways different. One can look at their equations and see striking similarities, yet in the subtle differences there rest different philosophies. The models we have heard reflect all the theories that have developed from Marxism up to our times. An implicit assumption can be made that sooner or later we will be able to improve the models to a point where we can produce some more or less unambiguous policy. There is some hope that ultimately the right data and the right theory will emerge. The question at this point is how quickly we might be able to achieve such a theory. There are several time lags involved. For instance, when the European Communities Statistical Office input-output tables will finally be as good as they can possibly be, there will be a five-year lag between the reference period and the year of publication. Facts like these set an upper limit to what might eventually be achieved in a model. In the present state of the art, we are being pushed more and more into what is publicly called scenario analysis. We recognize that there is a great range of exogenous variables that we do not understand very well, such as population, which in fact has not been discussed in great detail here; maybe there is simply a lack of sufficiently good theories on possible demographic transitions. In some models there is the implicit assumption that the demographic transition would come first, through some sort of birth control policy; and that, once this was achieved, it will be possible to raise living standards. In other models, a very different view is taken: only after raising living standards can demographic transitions be achieved. Of course, the direction of causal relationships assumed is of fundamental importance to the view of the policies to be advocated. If one takes population as an exogenous variable, one is forced to choose between forecasts that range from anything up to 50 billion people down to three or even two billion people. High or low forecasts are not necessarily optimistic or pessimistic; for example the Heilbroner forecast, which is one of the highest, is a Malthusian forecast. Of course, what is chosen is normally some kind of middle forecast. Similarly, if we look at food per capita we find that the modeling studies tend to be in the middle range of forecasts, but pictures vary widely. In addition to Bruckmann's remarks on the relation between optimism and pessimism on the one hand and differences in methodological approach on the other, I might add that nonmodeling writers do not aggregate in the same way; they are much more selective in their approach. A pessimist can easily select the numerous agricultural projects that have gone wrong, while an optimist can select a substantial number of projects that have gone right; and in the implicit production function that one may have in mind, one is more optimistic or pessimistic than the modelers who have aggregated across countries or nations.

The Linnemann model, it seems to me, has a sort of "beggar thy neighbor" theory underlying it: a rather unhappy view of the world, but, as many cynics would claim, a realistic view. One must impose quite altruistic policies on such a model which are not in the least consistent with its implicit "beggar thy neighbor" theory. And this is how one should carry out policy analysis on the model: every assumption must be reviewed because otherwise one may no longer have a consistent theory. If one stepped right back from the model one might find that many relationships within it no longer hold their original value. This is frightening to the modeler: having spent a great deal of time trying to establish a production function, he might find that he cannot be confident that that production function really means anything. The same applies to elasticities of demand and a whole range of other determinants. So whether one likes it or not, in examining the policies one necessarily moves into the arena of nonmodeling speculative future studies and political studies that other futurists are working on. We should always be aware that a possible consensus among modelers may have come about simply because of the communality of methods and structures.

The difference between modelers and nonmodelers relates also to the difference between micro-sociological studies and the microscopic modeling studies which I shall discuss later. I know development economists who consider the whole modeling game completely irrelevant. They concentrate on the level of the village; it has been emphasized also at this conference that some value might be derived from linking village studies to global modeling efforts. From a mere quantitative point of view, however, it would be difficult to achieve this link. To build a work model that takes into account all the issues with which people are concerned would, even in a greatly simplified manner, have to include 100 countries, 50 foodstuffs, and so on. Such a model might end up with something like 20 to 24 variables, most of which cannot be measured. So one is forced to focus on one specific issue. If one does so, however, one must recognize that one is looking at a limited area of understanding; and it is somewhat misleading to call this venture a global model. At best the overall global model we might arrive at may be considered the conglomerate of all the global models that we possess. However, the properties of that overall model are different from those of the global models taken singly. For one thing, it represents a great range of views, and has tremendous uncertainties that would be almost impossible to erradicate. Hence, I would hesitate to call it a censensus global model. It might at best be sort of a medium model, concealing the great variation and diversity that exists around it.

There seems to be one consensus, namely that with very few exceptions the models do not seem to hint at any major problem in the foreseeable future; all the problems are anticipated in the more distant future. I may recall that Linnemann in his initial exposition sharply resented the notion of "triage"; and if nothing else emerges from a conference such as this, at least there should be consensus on a sort of declaration that, in spite of all the diversity of views the concept of triage should be rejected.

Rademaker also made a few general observations: It seems to me that the discussion has been handicapped slightly by the different ideas poeple have about the use of models and their purposes even if they are often not explicitly formulated. Although the purpose of the conference has been outlined clearly, the main aim of agricultural models as related to the future has remained vague. As Meadows has pointed out, one of the most difficult questions a modeler can be asked is "Why did you build that model, and what was its purpose?" There may be pull research -- people having ideas, laboratories generating new developments, and so forth -- and in time some of it may turn out to have useful applications. There is, however, another type of research, which starts from the desires of people, from possibilities in the markets, and then works its way back to what is needed to satisfy those needs.

I wondered to what extent our models are pull models, or models explicitly designed to serve certain needs. I think this should be kept well in mind; one should not speak about policy alternatives if one has not identified the recipient of the advice one is going to give, let alone provide the details necessary for the recipient to make decisions and choices for the future.

Another point I wish to make concerns a sharp distinction between forecasting and predicting. One does not need a model to make a prediction. Any fool can make a prediction; any fool can even make a prediction that turns out to be right. Forecasting implies thinking about things that may or may not happen in the future; it implies thinking about the range of alternative futures. And the outcome of that process of exploring the future will normally not be the prediction. The outcome may very well be that forecasting cannot be done with models at all, or that one has been working on the wrong kind of models and will have to develop others. And the outcome of forecasting with these other models may again be that one has been working on the wrong models because one might have been hunting the wrong problem. I should like to define forecasting as logical coherent thinking about possible futures.

Underlying these thoughts, there is a growing conviction that society is something that can to a certain extent be designed. We are moving away from the fatalistic point of view that society develops entirely of its own, has its own forces of destiny, and that mankind can do nothing about it. We are moving into an area where -- right or wrong -- we have the feeling we can design future society, and that again is a justification for thinking about the future. And yet, I consider it very important to always keep in mind that what we do when thinking about the future is nothing but another way of thinking about the past. A historian was once defined as a backward-looking prophet. When alternatives are computed by use of input-output tables, this means nothing else than going back in history ten years and redoing these ten years in an alternative way.

I wish to comment on three topics: purposes, recipients, and techniques. Much of the discussion has proceeded on the assumption that forecasts have only one purpose. I consider this misleading. One kind of forecast for example gives a specific warning to specific policy makers; such a forecast is entirely different from the forecast one may find in "Limits to Growth". Another kind of forecast is intended for those planning certain things: a big irrigation system, some major technological development, and the like. Yet another kind is applied by the management of a large concern. There is a kind of forecasting that aims at mobilizing public and scientific opinion. One must keep in mind the broad purposes of forecasting to understand better why someone who has been aiming at mobilizing the public may be completely at a loss with policy makers, or vice versa.

In this connection, I wish to state that recipients have received remarkably little attention during this conference. The problem of tuning forecast reception may prove far more difficult than forecasting per se. One knows from business consultancy that very often the consulting job is unsuccessful because of the various actors involved: the man who ordered the forecast had no interest in it and no power to change things. In agriculture it may be similar: a government or sponsoring body has the money to ask for a forecasting study. This is very often a different body from the body that will have to carry out the results of the forecasting, which again may differ from those who have the power to change real life in such a way that we may be heading for a better future.

To return to the technicalities: if you want to look back into the past with a view to the future, you have three mental tools available: theory, data, and the power of thinking. We are too little aware of the development of mathematical modeling. A few decades ago, it was not respectable to base models on anything but theory. Only in the past decade has it become more fashionable to fill in blank spots of knowledge with statistical or empirical analysis. Furthermore, it seems to me that one of the big breakthroughs of Forrester and Meadows' work was to go beyond a certain period and apply the power of imagination where theory and data were lacking. The strange thing is that the latter component, the power of imagination, to be applied wherever data and theory are lacking, is the very oldest tool available to man. It is theory and data that are the newcomers in the field. Both are relatively young. But in the field of mathematical modeling we stand in awe of theory, we have a high respect for data, and the use of conjecture where data and theory are lacking is frowned upon by many. Here we find a sharp distinction between fundamental scientists and applied scientists. The fundamental scientists will say: if I do not have sufficient theory and data, I refrain from giving an opinion. The applied scientist says: there are important things to be done, important decisions to be taken; wherever I do not have sufficient theory and data, I will use my mind to come to a reasonable and acceptable conclusion. Engineers have been doing that all along, but rarely in an outspoken way.

We have also not been very clear about whether we are speaking of short-, medium- or long-term forecasting. Nor would we be able to achieve any workable concensus if we discussed that issue at great length. It seems to me that we have spoken mainly about medium-term forecasting. This is a bit easier because discontinuities, unexpected things that may happen, are less important. For the same reason, I would claim that mathematical modeling may be most suitable (or least unsuitable if you like) in the medium-term forecasting field. In the real long-term, the main interest would have to focus on discontinuities; models may help to ascertain certain discontinuities but certainly not all of them.

When I came to this conference, I had a relatively clear view of the existing agricultural models. I must admit that I am now almost completely confused, which means I have learned something about them. The only thing we know for sure is that every model is wrong, and every approach is wrong, or at least contains a number of wrong aspects. In this state, consensus is about the most dangerous thing that could happen to the field of agricultural forecasting.

Finally, I think we should speak neither of optimism nor of pessimism in this area. These are categories belonging to journalists, statesmen and others. What we must try to be is realistic. And if we want to be rebels, let us be careful rebels, combining compassion with precision.

Rabar added the following: In my opinion there seem to be some contradictions. One concerns the possible consensus. Cole explicitly asked that we declare our consensus on a few items at least, namely that the technical possibility exists to produce sufficient food, and our rejection of the notion of triage. Rademaker, however, said that consensus is the most dangerous thing we can imagine. This seems to be related to another kind of consensus. Perhaps we should discuss this further. In spite of Cole's belief that there is general consensus that the problems are mainly institutional, I think the mere fact that the models are attacking different problems contradicts this opinion. So may I ask those who built the models: how far do they attack the institutional problem, and if they do not, is it because they have different ideas about the main purposes of their models?

Meadows stated: I share Rademaker's opinion. I am emerging from this conference more confused than before, and I think that is a very good sign. One is forced to start at the beginning, to ask where do we go from here? And, may be more important, to ask: what are we missing? So we should go back and first ask: what is the problem? Having tackled that, we can hope to get back to what is the best method to attack it. Perhaps the best thing to recognize is that all the methods we use are necessary, but should be used with caution. Before we go on to modeling, we should at least understand the differences of underlying opinions. Otherwise, I do not see how models can help.

Most people will agree that there exists a problem that requires action. But what actions are required may lead to disagreement. Perhaps the best way to settle this is to look at the kinds of actions being advocated, because those who have a model will somehow have to incorporate these policies.

Basically, one set of policies concerns the redistribution of food, or income or capital or -- some kind of redistribution. Secondly, food can be produced better, differently, or in greater quantity. A third set concerns everything involved with controlling population growth. Almost every policy mentioned so far falls into one of these three categories. And it seems that there is a certain inclination to focus on one of the three policies and to neglect the other two. Redistribution, if it could be implemented, would have a fast effect on the system. Food production takes a little longer, and population control requires the most time; it may have almost no short-term effect, but over a long-term, it has a very large effect.

The Linnemann model is directed at redistribution on an international level. Other models that have not been discussed here deal with various ways of controlling population growth or of optimizing food production and the like. Maybe we are to a certain extent jumping ahead of ourselves. Most probably, a mixture of all three policies will be the most effective and, of course, there are many connections among these policies. I think most of the emphasis should not be on each one of these three policies, but rather on their connections.

As to the political side, people in those countries that would have to bear the burden of redistribution most tend to look mainly on food production policies; all around the world one sees very little interest in population policy. This is the real underlying reason why there was little objection to leaving population as an exogenous variable. Population is likely to be left out for the reasons that Cole would like us to form a consensus on. Since there are no limiting factors in immediate sight, and apparently since other people believe the population problem will take care of itself in time, there seems to be time enough and we do not need to worry at all. I just would like to remind you that a characteristic property of complex systems is that they are limited by their most limiting factor. Only one limiting factor is required if everything else is in abundance, to have a strong influence upon the system. In my opinion, capital will be the most limiting factor. In the U.S., the energy plan requires at least 50% of all gross capital formation over the next thirty years. This may even rule out expansion of food production. Apparently, this is not the time for us to start asking in detail how to distribute food, how to produce food, but rather what will be the connections between distribution of food, production of food, and how will that affect population growth?

Linnemann expressed the following: As regards Meadows idea on the need to include all the relevant aspects in a good model. I feel it is not sufficient that these aspects be included; there should also be some way of answering that the assumed relationship holds.

Meadows agreed: To leave out a relationship is the most inaccurate thing one could do; even a bold guess of a relationship is always better than an omission of the relationship entirely. The basic question is whether we feel that the world has to go ahead on the basis of imperfect knowledge or whether we can assume it to stand still for a while waiting for perfect knowledge.

Gallopin commented on the role of models: I agree with what has been said about this need for many models as a consensus at this time of the development which is by far too premature. On the other hand, I think we should not limit ourselves by saying no model is really true, that each model must have its biases and errors, and is only a particular picture of reality from the point of view of the modeler. In my opinion, to attain some degree of credibility and robustness, we must simply work on as many models as possible and observe whether there is some convergency on the main issues. Of course, one must avoid comparing only these models that belong to the same class.

As to policy recommendations, I share the opinion expressed by Linnemann. It would certainly be desirable, if possible, to associate through policy recommendations something like a factor of credibility. If every model came up with two or three policy recommendations, some of them would be based on weaker hypotheses than others. So, in principle, it should be possible to associate with the output some qualitative degree of probability with respect to the hypothesis. This might prove to be an interesting point of discussion for future work.

In the discussions at the Conference, there seems to be some form of concensus that the limits to full production are essentially of a socio-political rather than of a physical nature. If this is true, the conclusion might be drawn that there must be policies that could solve the problems and therefore merit deeper investigations. However it is an illusion to believe that, in the near future, an inclusion of socio-political factors explicitly in the models will be achieved at the present state of the art, even though it would be recommendable. In our model we simply assumed that the political changes can be implemented, without examining the question of how easy it might be to carry through these changes. However, I recognize that this is not sufficient. Another thing we will need in the future is models that could work with fuzzy, vague or qualitative information. All our models were derived too strongly from the engineering sciences. It is therefore not enough to make sensitivity tests, because there are many qualitative variables which are not included in the model. This inclusion of qualitative variables will be sufficient since most of us are mainly interested in qualitative results anyway.

As to optimistic versus pessimistic projections, I found in my work that, in most cases, pessimistic projections assumed the complete maintenance of current socio-political constraints, whereas the optimistic ones assumed that these factors can be changed.

As to the population question raised by Meadows, I agree that this is a very critical point. We therefore had a well-defined population model within our model; we tried to show that population stabilization can occur from increased standards of living and not from enforced population control. I wish to add that any imposed population control is, and will be, much more difficult to apply in an underdevloped country than is population control resulting from production increases.

In our model, furthermore, we did not find that capital proved to be the limiting factor; the limiting factor simply was the existing political and social contraints.

Rabar returned to the hypotheses express by Cole--there is overall agreement that the food problem is mainly an institutional problem.

Linnemann commented briefly: From our study, it is obvious that institutional problems are perhaps the biggest ones. I also agree with Meadows that the three policy directions cannot be disconnected. As to the consumption side: as long as consumption of food is determined by income levels, one has to take into account that people in higher income brackets consume more food because they consume processed food, which is also an institutional aspect, if you like. So I might say that our group sees the major problems in the field of distribution.

Gallopin opined: the Bariloche model takes care of all three directions mentioned by Meadows. We have a population sector, a food production sector, and a socio-political scenario which is not explicitly shown in mathematical form, but which enters by assuming an equal distribution for all people. Furthermore, we show that one cannot control population directly; population will grow, but will stabilize by itself on a level much higher than the current level. I would be very much in favor of a model that would include explicitly the socio-political restraints.

Bottomley inquired: Does one really need to worry so much about these socio-political contraints. We know that for a long time conferences have been going on about land reform, rural credit, employment, and so forth. The recommendation formulation by these conferences might lead the modeler to the conclusion that if these actually were taken, this would immediately lead to a different distribution of income and wealth that might alter elasticities of demand in the world in certain directions. These inputs could be made readily available to modelers and could be used for modeling purposes.

Kaya agreed that institutional or socio-technical problems can, to a certain extent, be included in a model. He stated: I think it is more important to realize that the model is not an almighty thing. Even if we have a good model, it is impossible to explain everything through that model. Models will never be able to give exact solutions to problems.

Tarjan noted: Institutional problems are the most important ones. If, for example, in the Sahel-Sudan region we had done a single model, we probably would not have been able to identify the sort of institutional problems that we did identify in our analysis. Consequently, perhaps our "model" should be called the systems approach rather than the single model. What we have done was to connect several models of the various sectors of the economy; this could also be done for global models.

I have great doubts about any particular single model. For instance, the basic assumption of MOIRA is income and price elasticity of demand and its impact on production and other factors. Will that still be true five years from now? Any false implication has high opportunity costs; if we accept a false implication of any particular model, this means that we forgo an alternative opportunity. All alternatives of this kind might be forgone if one sticks too closely to the implications of any particular model.

Linnemann focussed attention on a few issues previously raised: Cole and Gallopin have claimed that the basic philosophy of our model was a "beggar thy neighbor" behavior. Also, I do not think one should distinguish between optimists and pessimists. I think one should rather speak of a model reflects reality, whatever the reality is; and if this results in a pessimistic view, it certainly does not mean one cannot use this result to introduce a policy to change this realty. One could turn this around: the only way to have really optimistic solutions is to have a pessimistic problem statement. So a model should try to reflect or depict reality as accurately as possible. Therefore, we deliberately did not start developing a model for any ideal society; our starting point should lie as much as possible in reality. Of course different people may have different perceptions of realty; for model builders this is a tremendous problem, but who is going to tell the model builder what reality really looks like? We felt, however, that in the fields of agriculture and of agricultural economics there is sufficient agreement on certain basic principles of mechanisms or theories, whatever you might wish to call them. On the other hand, we felt that in other fields such as ecology, the state of the art is comparatively speaking so undeveloped that, from our discussions with various ecologists, we were unable to derive any common view, any general principle that we would have been able to build into our models. That was the reason why we left out most of these aspects. The same holds for biological and geographic factors, as well as for labor productivity, food consumption and the like. Nevertheless, we admit that a model is only a picture of reality and can never be a substitute for reality: it is only a simplification. At best, our model will be able to be used as a conditional forecast. If we take reality as we see it today as our starting point, indeed there is a good deal of pessimism in the model. It is therefore also true that most nations have behaved in what has been described as a "beggar they neighbor" policy.

Kamrany agreed: We may have different perceptions of reality, but a scientific approach should be based on more solid ground as to the way it pursues its work.

Gallopin added the following: One avoids speaking of pessimism versus optimism at large, and should be careful to say in respect to what. We are, for instance, optimistic with respect to thinking that there are no physical limits, but we are pessimistic about what we think will happen with respect to reality: I do not really know what reality is. Is it reality to assume the permanence of political conditions of today for another hundred years from now? This has been disproved. Incidentally this is why I think that the inclusion of socio-political considerations in modeling work is essential.

Rabar observed: We all share the feeling that we should go much more into the details than our time constraints will allow us. However, I think we should again focus attention on concrete aspects of our problems. In particular, two problems seem unresolved: one is the single product assumption made by MOIRA, and the other one is the real role of prices in the model. Can we make a comparison of how prices work in different models?

Gallopin objected to the observation that every model presented here contains these problems. He added: Our model has at least three commodities in the food sector, each of which serves as an indicator for a broad class of categories. Price in our model is used as a policy instrument in order to allocate labor and capital in an optimal way to different productive sectors.

Linnemann made this following point: We have explained at such length why we limited ourselves to a one-product approach. The main reason is that disaggregation on the product side requires a description of individual product markets or of groups of product markets; this might be a rather cumbersome thing in itself, aggravaged by the fact that input data may not be specified as to the type of commodity grown. Nevertheless, we feel that a certain disaggregation would be desireable, mainly disaggregation among food products and non-food products. This is one direction we should pursue in our future work.

Rademaker did not think that one should regard the MOIRA model as a single product model. The model has started with an investigation of the production in each country, considering fifty major food crops and then aggregating them into a single artificial commodity, consumable protein. At least the production side must be considered, by far, more detailed.

Linnemann stated that as to how far to disaggregate depends very much on what one is ultimately trying to do with a model. What for some questions may be a central aspect may be insignificant or less important for other questions; the basic message about the amount of hunger in the world would not have been altered substantially by a disaggregation of various commodities.

Global Modeling of Food and Agriculture: Background to a Possible Approach*

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: Universe 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 general models are needed. The word general, however, has a variety of meanings. When used as an adjective modifying approach, 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 general is also used as an adjective to modify the word model. 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 <u>position</u> globally and for selected regions and/or countries over a 1-5 year future time horizon,
2) to project the food population balance <u>trends</u> 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 adoption 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.

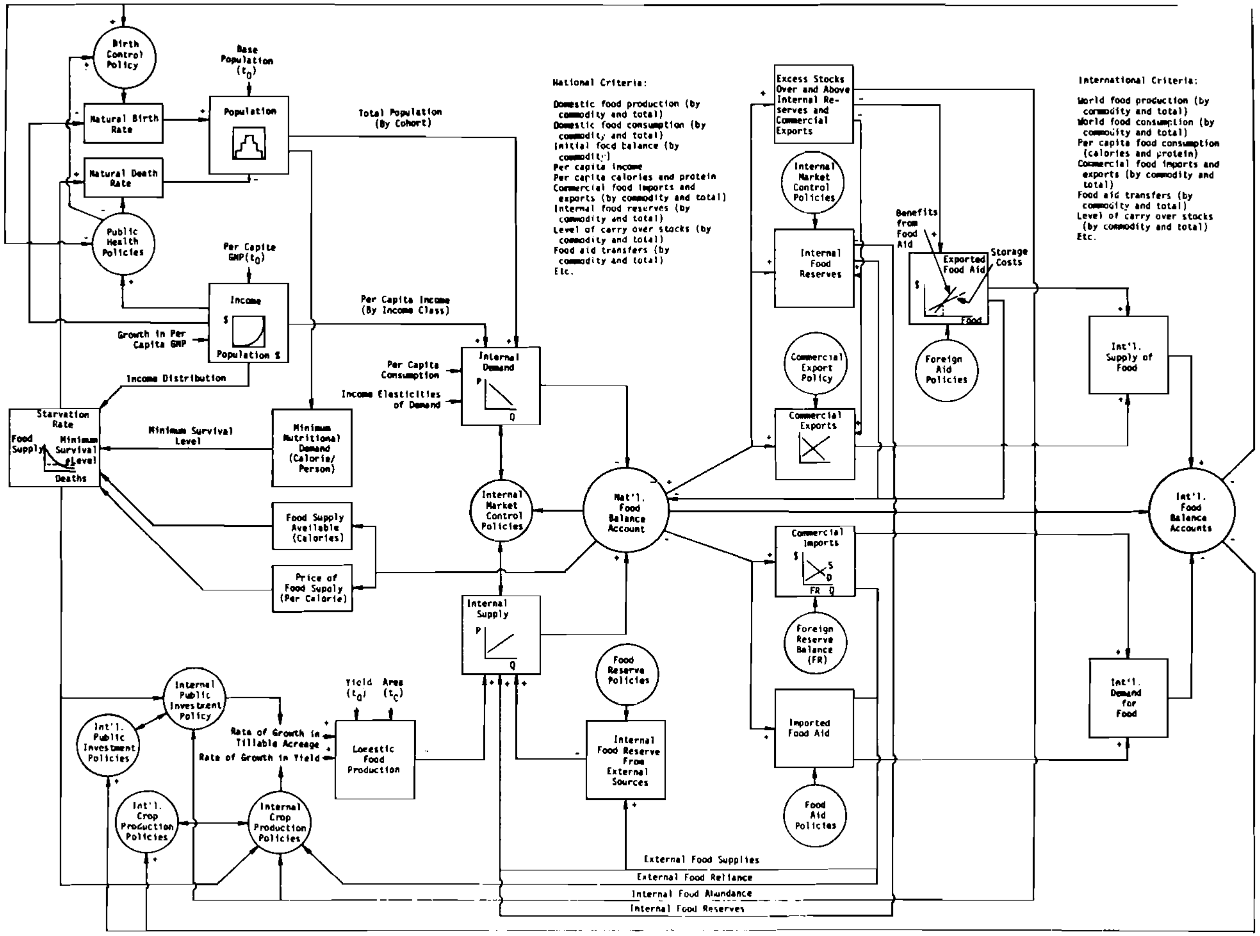

Figure 1. A Model Conceptualization.

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," <u>Psychology Today</u>, 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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Modelling Food Production: An Attempt to Assess Various Approaches[†]

Adolf Weber

ABSTRACT

The first part of the paper gives an overview of how different disciplines try to relate, and model food production. The main emphasis is not so much on formal properties of global models, but rather on comparing and contrasting different approaches, in order to be able to better assess their potentialities and possible limitations for further work.

The second part presents a cross-section analysis of population density, prevailing protein consumption pattern, fertilizer input and income per unit of land for more than 100 countries.

In the third and final section, some conclusions are drawn from the graphic analysis of part two with regard to further developments, in particular by comparing the Federal Republic of Germany and Kenya. The author concludes that it is absolutely essential that consumption of fertilizer and complementary inputs in Kenya be increased faster than the demand caused by population and by income growth. Every economic and research policy that reduces the real price of energy will, of course, help to increase food production per capita. Less energy-intensive production methods should be researched as matters of great urgency. Success will ease and remove some of the pressures exerted by high energy prices. In the author's view, however, a higher growth rate in food production will most likely result from an expansion of the use of energy-intensive technologies. Man's progress in science and the continued search for ways to exploit the inherited but limited energy capital are the weapons for winning the battle against hunger, malnutrition and associated problems.

[†]To be published in the *Eastern Africa Journal of Rural Development*.

Discussion

Bottomley referred to the suggestion by Rossmiller, supported by Weber, and by the chairman of the council, namely to set up a systematic data bank in this field. He considered this suggestion important, and wished to formalize it along the following lines. He proposed that IIASA try to provide the following:

1) Computer or information scientists, for a period of three years, who might initially work only part time. Full time employment might cost up to $100,000 which would require a foundation; part time service could involve an existing IIASA staff member, which might be more appropriate.

2) A library of computer tapes appropriate to world modeling that included not only agricultural modeling, but also world modeling in general; the data provided could be obtained by mail or by computer network.

3) The computer scientists mentioned under 1) above should try to persuade different modeling groups to provide tailor-made information to other groups. This could result in a mutual exchange of services among participating groups. Once a IIASA data bank is created, all contributors of the bank should try and build up credit by providing information, if necessary tailor-made. The data bank will be as good as its contributions.

Rossmiller supported the idea; however, he suggested that it be considered a part time venture. To keep the software packages updated and to keep the data bank current requires a substantial staff and supporting organization as well as much planning.

Millendorfer strongly supported the idea of the data bank, but added that he would like to see its scope extended to that of a formula bank. Very often, scientific groups in some countries arrive at relationships between one dependent variable and several independent variables; this relationship, if made available to other scientific groups, could prevent them from large-scale misallocations of resources. One example would be to collect the studies of the relationships on fertilizer input and the agricultural production in different countries.

Bernadini stated that he did not wish to speak negatively about the idea of a data bank as such; however, he wondered whether IIASA would be the appropriate institution. If IIASA were to undertake data collection to such a large extent, it might absorb all its other activities. Kamrany added that experience with many data banks has shown that they are very expensive and by no means used as much as one expected. De Hoogh drew attention to the fact that one type of data bank has been in existence for a long time, namely that of the FAO in Rome; it is an open institution and one can obtain all types of information desired. Of course, data are not complete, but it is a useful beginning.

General Evaluation

(Chairman: Gerhart Bruckmann)

Bruckmann invited Keyzer to discuss the question of the use of cross-sectoral data. Keyzer explained his idea: problems may arise when a non-linear function is *estimated* on a country level, and is *used* on a regional level. Even more problems arise with section estimates, especially with respect to the cost and the dynamics of the system. While this may sound technical, these aspects are normally neglected in the discussion of models.

Cole admitted the seriousness of the problem; since the data base is often weak, one should view it in its proper context. The use of cross-sectional data for forecasting purposes implies that more less developed countries will follow the patterns of the more developed countries; this is where the problem eventually lies. Even if this were true for the less developed countries, what can be said about the more advanced countries?

Millendorfer drew attention to the fact that in his investigations of cross-sectoral data, he and his associates were able to distinguish clearly four major groups of countries with a surprisingly large homogeneity of production functions. The criticism of other speakers was valid but often one has no other choice; one needs to rely upon what limited empirical information is available, and to get as much information as possible.

Bernadini and Cole felt that perhaps it is best to apply a mix of cross-section and time analyses wherever available. Cole added that one should set some bounds to the degree of success that might be ultimately achieved.

Keyzer added that more attention should be given to the predictive value of models. The falsification criteria are not only in the realm of the causal insights they provide, but one needs to further examine the reasons why so many of the present models work so poorly, and why for instance in the U.S. a simple model in the monetary field works better than more complicated models.

Batteke stated that a number of problems reamined unsolved: the first one was directly related to Keyzer's last remark. The predictive value of models has often been poor, because one neglected certain quantum jumps owing to synergistic effects. One example, the Arab oil crisis brought about a speed limit on U.S. highways of 55 MPH, which in turn resulted in a drastic reduction of fatal road accidents; this restriction might otherwise never have been introduced. Such synergisms will always overthrow a model, since one cannot rely on the long-term constancy of correlation coefficients. To a certain extent science fiction might help to determine where and under what circumstances such quantum jumps have to be considered.

Cole added that an improved forecast need not be one that predicted the true outcome accurately; rather it should yield a greater understanding of the complexity of the situation.

Before proceeding, Bruckmann informed the participants that Levis kindly agreed not to read and discuss his paper to allow more time for the general evaluation. He then proposed that discussion take place on the problems of the agricultural production function.

Waelbroeck wished to clarify his comments on Thissen's paper. Since most production functions used in world modeling show some leveling off, they must eventually end up with some kind of "limits to growth". As to these asymptotes, he did not believe that they are based on serious data. Levis added that his extensive investigations have revealed that the asymptotes assumed for the production function moved up as time proceeded. However, as soon as one starts to plot the movement of the asymptote, there is no longer a limiting value.

Millendorfer stressed the fact that most production functions neglected the educational aspects. In his investigations, he found that education--that is, quality of labor,technological progress, the increased advantage of knowledge, the ability to take this knowledge into account--plays a substantial role that is much more important than many other factors normally considered.

Quance raised another point: he felt that a response from the supply side was missing in most production functions. If one increases the price that the farmer receives, there is usually some way that the farmer can increase production, in spite of government regulations. Thus one should pay more attention to transforming production functions into supply response functions; the world food problem may be more strongly related to economic factors or to production costs than to other factors. That is, you will not find a hungry person in the world with money in his pocket.

Cole pointed out that there is a major difference between production functions with more or less extrapolating past experiences and technological utopias that describe vast deserts being turned into flowering orchards. Fundamental parameters needed to bridge this gap may be found in the cultural, social and technological factors; these should be examined more thoroughly.

Bruckmann suggested that the discussions focus on the question of how to assess "soft variables", a topic that was not unrelated to the subject of social versus physical limiting factors and institutional versus technological problems. In his opinion, an economist's model ends where the true problems begin: if an economist, for instance, states that 2% of the GNP can eliminate pollution, it is at this point that he considers the real problem. Why is this not being implemented? What are the odds that this 2% will be spent, and what changes will have to be made to arrive at that point? In our modeling work, if we limit ourselves to the point where the traditional economist stops, we will never be able to claim that our models can be used as policy models.

Batteke agreed with Bruckmann. First there is the engineering feasibility of a solution, then the economic feasibility, and thereafter, at the least, the administrative question and the consideration of feasibilities. He therefore strongly suggested that one investigate more intensely both synergisms of this kind and the implementation of strategic modeling.

Quance pointed out that he had some experience with the possible application of modified delphi-panelling in order to make up scenarios of this kind.

Rademaker stressed the importance of making the modeling efforts suitable to the needs of policy makers, if the modeler wished to have his findings implemented with a certain probability. If a modeler dreams up a modeling project alone and then approaches a policy maker with the results, the project is almost certain to fail. However, in the agricultural field, there is no single policy maker, which makes implementation even more difficult than in other fields.

Levis mentioned the need to bear in mind the person using a particular model. In the Bariloche model and in MOIRA, there are strong assumptions made about values that deviate from the values in vogue among the decision makers concerned.

Millendorfer stressed the importance of paying more attention to the so-called soft variables. For example, one has a wrong policy for educational planning--one that would divert too many resources to academic education, and away from primary education where they are needed; the resources are therefore wrongly allocated.

Cole, supported by Bruckmann, underlined the apparent contradiction between the complexity of the model and its ability to penetrate: the more complex a model, the more difficult for it to penetrate into wider conscience.

Roberts stressed the need to distinguish (at least) between two types of soft variables. There are variables that one ultimately expects to be able to measure, and variables that are immeasurable. The notion of "quality" ranked among the second group, as it contains, to a substantial degree, esthetic values.

Rossmiller strongly supported this view. He believed that one way to incorporate soft variables in a qualitative sense is to work closely with the decision makers for whom one is modeling; thus in conceptualizing the model structure, the modeler can give some attention to the soft variables. One can go a step further in setting up policy experiments. One can often convert or use the hard variables as proxies for soft variables.

Bruckmann wondered thether it was possible to draw a strict boundary line between eventually quantifiable and nonquantifiable soft variables; M'Pherson appears to have arrived at a quantification of many variables that only a few years ago, would have been considered unquantifiable.

Cole felt it was perhaps more important to include soft variables in a model in order to understand the assumption being made implicitly about soft variables, when certain hard variables are being put in the model. For example, the Bariloche model contains more or less only hard variables, but implies a whole system of structural changes that can only be expressed by soft variables. This is not only legitimate, but also more honest than is the case where modelers do not try to become aware of the soft variables they are implying.

Bruckmann suggested considering among this class of soft variables all the tacit assumptions that go into a particular model. For example, both the Bariloche model and MOIRA tacitly assumed that the condition of the world's oceans will not deteriorate.

Quance stated that the major dilemma is that policy makers are interested in receiving only one projection from modelers; they do not wish to be confronted with a set of alternatives. On the other side, the modeler knows well that the probability of any one projection he gives to the policy maker is zero.

Millendorfer stated that he is not very pessimistic about the possible quantification of soft variables. In many functions, there are residuals that can be seen as a link for several soft variables. Even if these variables cannot be identified, their overall influence can be measured. To give an example from physics: we still do not know what electricity really is, but we use it.

Sanderson agreed that for many so-called soft variables there exists much past experience, and this experience can be analysed even though the tools may not have the same precision. Returning to the question raised by Bruckmann, why certain changes are not being implemented, he stated that one answer may be institutional constraints; institutional constraints are again a catch variable containing the whole package composed of the educational, political, psychological and insitutional limits to development. Wherever the general economy grew fast, agriculture also grew fast; so there is certainly an interrelation between the general economic growth and the speed of agricultural development. This can be studied more closely and can be build into a scenario. But other aspects can also be included: the extension of mass education in many countries is another soft variable subject to some degree of measurement.

Sen commented on social versus physical limits. It appears that too much importance may be attributed to institutional factors; they are important but seem to be overestimated. In some countries or regions, great improvements were made over a very short span of time, without any accompanying institutional changes, as for instance, in India. He did not believe that physical limits, as they seem to exist at first sight, represent an ultimate limit; they can be changed. For example, the physical limits in parts of Africa can be changed by proper irrigation. Many technological changes can result in great improvements without necessarily adding basic production factors.

Cole added that one should not look at production alone. For example, total food production in China does not appear to have increased much, although malnourishment has been greatly reduced. On the other hand, there has not been a great improvement in the nutrition levels of those persons in parts of India where large production increases have been realized.

Waelbroeck added that one institutional factor that is neglected in most models is international trade. Trade may not be a major obstacle in Africa or Latin America, but certainly represents a serious problem for many Asiatic countries. This was one of the reasons why MOIRA concentrated deliberately on the function of international trade.

Bruckmann suggested that the meeting discuss the relation between the modeler and the policy maker, how to assess the implementation of models, the working techniques of modeling groups, and also their mutual relationship.

In Brioschi's opinion, it was best to proceed by modeling on a highly aggregative basis, while at the same time structuring such that the model can be broken down on a more restricted regional basis. Collecting data is not sufficient; it is important to establish a framework so that at the national level the model has a certain organization that can be studied and comparable data can be collected.

Quance referred to Rossmiller's suggestion to create a central computerized library of agricultural data, relations and simulation models. One intermediate step toward that goal might be to test the feasibility of such an idea: to first sponsor an international symposium on food and agricultural models, at which a task force would develop global and national scenarios; all interested groups might use their own models and make projections of these alternative futures. At a workshop, differences could be compared and brought into an overall picture. Gaps and overlapping areas could be identified in the models, and future steps might be designed to alleviate these. This method would be much better than to arrive at some specific overall world model that would be believed in too strongly.

Roberts drew attention to the fact that this is exactly what happened in the so-called LINK model, a short-term econometric model that ties together many nations, including their exports and imports. He reminded the participants of the great difficulties that had to be overcome in establishing this type of cooperation.

Waelbroeck agreed but added that in the LINK project, these difficulties could be overcome and the model was functioning for about five years now. There is a large amount of work involved in ensuring that the national models linked together remain comparable.

Bruckmann thanked the participants of the conference.

Rabar summarized the scientific result of the conference, saying that he and (hopefully) all the participants felt they had learned much about different approaches, methods, problem settings and the like. He expressed a certain disappointment that so little had been achieved in assessing properly the main world issues in the field of food and agriculture; there remains much to be done. There are many diverging opinions that must remain so since the data base for resolving these controversies does not exist. He was pleased to state, however, that one general concensus emerged from the conference: the developed nations have a moral obligation toward the developing nations. More research must be conducted in every field concerning the different limits including institutional and noninstitutional limits.

Levien, in a closing address, stressed the productive and exciting nature of the conference. From the point of view of IIASA, there are two benefits that have emerged: the fact that this excellent group of experts was brought together may have facilitated a kind of scientific cooperation and collaboration which may eventually help to resolve this most important question. The second benefit is that since IIASA is beginning a program in food and agriculture and also is continuing its extended interest in global modeling, it is able to profit greatly from the wide expertise present at this conference.

Appendix 1

Agenda

Monday, 22 September

09:00-10:00	Registration at the Club Hotel	
10:00-10:15	Welcome and Introduction to IIASA	Levien
10:15-10:30	Introduction to the Conference	Rabar
10:30-12:30	MOIRA: A Model of International Relations in Agriculture	Linnemann & van Heemst
14:30-16:00	MOIRA (continued)	Linnemann
16:30-18:00	MOIRA (continued)	Linnemann & Keyzer

Tuesday, 23 September

09:00-10:30	MOIRA (continued)	Keyzer
11:00-12:30	MOIRA (continued)	de Hoogh
	Other Food Models	
14:30-15:00	Modelling and Optimization of Complex Development	Kulikowski
15:00-16:00	A World Agricultural Model: An Input-Output Research Proposal	Bottomley
16:30-18:00	A Hierarchical Multination Link Model for Development Planning: Balanced Development between Agriculture and Industry	Kaya

Wednesday, 24 September

	Other Food Models (continued)	
09:00-09:45	A Conceptual Overview of Agricultural Models	Meadows
09:45-10:30	Latin American Food Model	Gallopín
11:00-11:45	Food Production in Certain Asian Countries	Roberts & Norse
11:45-12:30	The Pestel-Mesarovic Food Model	Richardson
	General Problematique	
14:30-15:15	Food Problems and International Trade in Cereals	Etienne
15:15-16:00	International Food Fund Concept	Kamrany
16:30-18:00	World Agriculture: Reassessment of Trends and Policies; long-term prospectives for the world grain trade	Sanderson

Thursday, 25 September

	Methodological Problems	
08:30-09:00	An Analysis of the World 3 Agricultural Submodel	Thissen
09:00-11:00	Panel discussion (Bottomley, Cole, Gallopín, Kamrany, Kaya, Linnemann, Meadows, and Rademaker)	
11:30-12:00	Global Modeling of Food and Agriculture: Background to a Possible Approach	Rossmiller
12:00-12:30	Modelling Food Production: An Attempt to Assess Various Approaches	Weber
14:30-16:00	General Evaluation	

Appendix 2

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Appendix 3

List of Additional Papers[†]

Models of World Food Supply, Demand and Nutrition
John Clark and Sam Cole

Common Agriculture: Policy and Practice
G. MacKerron and H. Rush

India's Prospects for Self-Sufficiency in Foodgrains
Bandhudas Sen

Progress, Difficulties and Prospects of Agriculture in India
Gilbert Etienne

Population and Agriculture in China, Present Situation and Prospects
Gilbert Etienne

Attitude of the People's Republic of Bulgaria on the Project MOIRA
Todor Popov

AGRIMOD: A Policy Analysis Model of U.S. Food Production
Alexander Levis, Stephen M. Haas, Elizabeth R. Ducot, David G. Luenberger, and Robert E. Larson

The Italian Food Sector: An Input-Output Model
U. Bertele, F. Brioschi

Long-Term Perspectives for the World Grain Trade
Fred H. Sanderson

The Great Food Fumble
Fred H. Sanderson

[†] available from IIASA as Preprints