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Latin American World Model. Proceedings of the Second IIASA Symposium on Global Modelling

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LATIN AMERICAN WORLD MODEL PROCEEDINGS OF THE SECOND IIASA SYMPOSIUM ON GLOBAL MODELLING

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PREFACE

The mathematical model presented here is normative; the concern is not with predicting what will occur if the contemporary tendencies of mankind continue, but rather with sketching a way of arriving at the final goal of a world liberated from backwardness and misery.

Any long-term forecast about the development of mankind is based on a view of the world rooted in a particular value system. By assuming that the structure of the contemporary world and the set of values which sustains it may be linearly projected toward the future, we are in fact taking a position. In this sense, the difference which is usually made between a projective and normative model is essentially fallacious.

The idea of constructing this model springs from a meeting held in 1970 in Rio de Janeiro sponsored jointly by the Club of Rome and the Instituto Universitario de Pesquisas do Rio de Janeiro. The meeting analyzed and discussed the results of the World Model III which was constructed by the group headed by Meadows at the Sloan School of Management of the Massachusetts Institute of Technology (MIT). As a result of the discusion of the basic assumptions of the World Model III, a group of Latin Americans attending the meeting decided to assign the Fundacion Bariloche of Argentina the work of constructing a world model that encorporated the views expressed at the meeting.

A Committee was formed composed of Helio Jaguaribe, Carlos A. Mallmann, Enrique Oteiza, Jorge Sabato, Osvaldo Sunkel, Victor Urquidi, and Amilcar Herrera, which in September 1971 issued a paper giving in general terms the fundamental hypotheses and variables to be used in the Bariloche Model. This preliminary project was submitted to the annual meeting of the Consejo Latinoamericano de Ciencias Sociales (CLACSO), held in Buenos Aires in December 1971.

In mid-1971, a meeting was held at the Fundacion Bariloche, attended by the majority of the members of the Committee as well as by some of those who would later be involved as authors in the project. The meeting defined the essential features of the Model to be developed. The Committee appointed a Project Director, and entrusted him with the task of forming the group of specialists who would construct the model. In the final phase of the project Hugo Scolnik was appointed Co-Director of the project.

While an individual author has reported on the main task assigned him, this in no way reflects the real participation that each had in the work. The hypotheses and basic philosophy of the model were the product of a long and difficult collective task, and it is almost impossible to distinguish the individual contributions.

The initial group which gave rise to the project constituted itself thereafter into a Consulting Committee, with the mission of periodically carrying out a critical analysis of the progress of the work. Its criticisms and suggestions were a valuable contribution to the task performed. It is appropriate to point out that final responsibility for the ideas contained in the model is with the authors.

An initial contribution was received from the Club of Rome to carry out a study on the project's feasibility. Thereafter, the execution of the project was financed in full by the International Development Research Centre (IDRC), Ottawa, Canada. The authors wish to express their gratitude to both institutions for the total academic freedom given them.

Amilcar Herrera

Buenos Aires, August, 1974.

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Opening Remarks

Tjalling Koopmans

Let me welcome you on behalf of Professor Howard Raiffa who regrets that unexpected and imperative IIASA business has prevented him from attending the Conference. However, he has offered us some written suggestions as to the nature of the Conference. I want to welcome all who have come, in the first place, Professor Herrera and his colleagues from the Fundación Bariloche who have made their ideas available for discussion at this Conference. Secondly, I should like to welcome the participants from many research groups in many countries who are interested in global modelling problems. Finally, a word of welcome to the IIASA staff members present and to those who will attend or participate in the various discussions.

The chairmen of the sessions will be IIASA staff members; at five of the sessions we will discuss various papers presented and the work of the Fundación Bariloche. Professor Bruckmann is responsible at IIASA for the work on global modelling, and will chair the last three meetings which will summarize the information presented and assemble research groups for various work on global modelling.

I would like to read the statement of Professor Raiffa on the nature of IIASA's interest, involvement, and support of the series of conferences on global modelling of which this is the second. I trust that many of you were present at the first conference devoted to the work of Professors Mesarovic and Pestel. Professor Raiffa's statement indicates IIASA's interest in supporting and facilitating the work of many research groups in global modelling.

"This is the second global modelling conference hosted by IIASA. While global modelling is not one of our major projects, it is something we want to monitor and cultivate to serve the scientific community. IIASA is providing a forum, concentrating on the methodological aspects of global models. Among our own scientists and supporting institutions there is a great difference of opinion about the merits of large-scale global modelling; it ranges from ecstatic support to negative skepticism.

"The concern in all these global modelling efforts is for problems of mankind in the distant future, and those concerns are concerns of everybody. They focus on aspects of food, agriculture, and the quality of life; there are the no-growth and the full-growth advocates, and we feel we should not ignore this field of endeavor. We do not want to favor prematurely one group over another. That is why we want to review in a series of symposia various points of view, those of the developed, the developing, the socialist, and the non-socialist countries; we want to hear what the arguments are and to learn about the various models. We want to obtain here the best documentation of these modelling efforts so that advocates of different points of view can come to understand other models. The tendency is for too much rhetoric and not enough scientific substance, and we are therefore trying to bolster the scientific side by having clear documentation readily accessible. This documentation, including computer software, will be made available to all who are interested in the developed and developing countries, in organizations, and so forth.

"We are already working on segments of these problems from the bottom up, for example our work in the fields of energy and water. Other attempts are being made from the top down. We do not know how much top-down modelling we will do at IIASA in the future. The present position is to find out what is being done in the field and what has to be done in order to ascertain what can be done here [at IIASA]."

PART I: PAPERS PRESENTED AND DISCUSSIONS

Introduction and Basic Assumptions of the Model

Amilcar Herrera

When the complex characteristics of the contemporary world are analyzed, it can be seen that almost two thirds of mankind live in misery and scarcity. Only recently has the minority begun to perceive the negative effects of over-consumption produced by increasing economic growth that is destroying the human and natural environment. This inequality, which has divided the world into developed and undeveloped countries, does not recognize rigid political boundaries. Some privileged minorities of Third World countries enjoy consumption levels equivalent to those of the upper classes of the developed countries, while considerable sectors of the population of the developed countries have not yet reached the full satisfaction of their most basic material and cultural needs.

The world is experiencing exponential population growth and consumption and an accelerated increase in environmental pollution, the two latter phenomena being produced mainly in the industrialized countries. For the first time in history, we are faced with global problems which can be solved only by action on a global scale.

As a result of this new global approach, some of the ideas of the classic economists such as Ricardo and Malthus are again current; according to Malthus the scarcity of natural resources would lead eventually to a decreasing social return of the economic effort, with the consequent delay and eventual halt of growth. He also predicted that the growth of the population and consumption (which have reached unprecedented levels) will exhaust the earth's natural resources; according to him this will probably occur in the near future. Although the natural resources may not be exhausted before a historically significative time period, pollution and the progressive deterioration of the environment will provoke the collapse of the ecosystem. In both cases, the result would be the same: catastrophic halt of growth, a massive increase in the rate of mortality of the population and the general lowering of the average standard of life to conditions existing prior to the industrial revolution.

These ideas caused various reactions, which in general terms might be divided into two types. On the one hand, there is the conviction that only a solidarious effort of all mankind can successfully confront the dual problems of increasing the living standards of the disposesed masses, and generating forms of progress and value systems to halt the deterioration of the human and natural environment. The second reaction, found mainly in the developed countries, makes population growth the fundamental cause of world problems. They believe that the control of this growth is an indispensable prerequisite for avoiding the catastrophe. The control of pollution, the rational use of the resources, and the like are only complementary corrective measures.

Those who share this position do not doubt the central values of the developed world. Their main contention sometimes clearly stated is that there are "natural" barriers to economic growth and these give little hope to the backward countries of reaching the levels of welfare enjoyed by the advanced countries.

These fatalistic statements contain a fundamental fallacy. Where there is a global set of problems, there exists sufficient degrees of freedom that make possible different alternative solutions. The solution chosen is always determined by the economic and political conditions of those involved in the decision process.

When Malthus stated his theory of scarcity (which has a scientific base that is neither better nor worse than the one on which the current catastrophistic positions are founded), the "solution" he postulated was not the only possible one as history later demonstrates. History also showed that Marx's refutation, which comes about a few decades after Malthus, was not valid. Viewing the situation with historical perspective, we now see that Malthus' position was advantageous to the interests of the British dominant classes. Marx's refutation derives not so much from a different appreciation of "reality" (which did not go beyond a theory with scarce empirical foundation) but rather from a different conception of the forces that determine the development of mankind.

Malthus' theory was implicitly or explicitly used by the dominant classes of his time, and it influenced salary and social policies during most of the nineteenth century. Its final goal was the maintenance of the status quo.

The formulation of "alternative solutions" stemmed from an ideological climate stimulated by the struggle of social classes and groups willing to reject an order which kept them at subhuman life levels. The acknowledgment that misery was a consequence of the prevailing social organization, rather than a product of a "unmodifiable natural law," becomes a dynamic element of change since it emerges at a historical moment when the oppressed social sectors become aware of their strength and objectives. They are the ones who, after an unceasing struggle, will be able to modify some of the negative traits of the society generated by the industrial revolution.

In many respects the contemporary situation is similar. Even though one may assume that the current course of mankind presents the danger of a collapse or serious lacks of equilibrium in the natural ecosystem, this does not imply that there is a single solution to avoid this. The enormous complexity of the social organization, together with the progress of science and technology, means that the degree of freedom possible for the "human system" is at present much greater than at the beginning of the nineteenth century.

The solutions now being proposed by the advanced countries are conditioned, as in Malthus' times, by the need to put them into a particular socio-economic and political context. They respond to the interests of the developed countries and, only as a function of these interests, are they posed as unique and predetermined. Even their humanistic "version" (that which postulates a return to nature, with the rejection of the "sophisticated" and massive technologies as intrinsically harmful) expresses the viewpoint of countries and certain social sectors within them which are now perceiving the negative effects of over-consumption and the potential danger of large masses of underdeveloped countries gaining access to levels of welfare. However, the danger is not in the continuation of technological progress but rather in its social use.

The Bariloche Model starts from the assumption that at least for the foreseeable future, the main obstacles to the harmonious development of mankind are not physical; rather they are social and political in nature and depend on the present distribution of power both at an international and national level. This is manifested in the growing inequality worldwide and within each country, particularly within the underdeveloped countries. This in no way ignores the fact that if the current tendencies of mankind continue, the deterioration of the physical environment might become a problem of great magnitude. It will probably not appear in the form of an absolute exhaustion of non-renewable natural resources, or of a lethal increase in pollution. However, the general deterioration of the natural human environment generated by a civilization, which has as one of its main targets to increase the consumption of material goods up to irrational limits, may create living conditions almost as catastrophic as the Malthusian scarcity.

We must accept the fact that mankind's effect on the physical environment depends basically on the social organizational structures adopted, and on the accepted values system. Much of the values of the present world are intrinsically destructive to the ecosystem, just as they are destructive to man himself who is overwhelmed by an ever increasing alienation. Mankind and the physical environment (where it is inserted) constitute a single system, which can only be described using socio-economic and physical variables.

The underdeveloped countries, which are the main victims of the system, find themselves in a historical situation which compels them to formulate solutions that take into account the possible degrees of freedom; it is these countries whose interests coincide with the need for changing a social structure which objectively hinders the development of mankind.

The following sections of the Report sketch a possible world in which there are new ways for human development. The main objective is to initiate discussions which take into account some of the most important factors involved in the global problems faced by mankind.

BASIC ASSUMPTIONS

The proposals contained in the Model to overcome the obstacles to the development of mankind start from the following main premises:

a) The catastrophies predicted by some current models (whether mathematical or not) constitute an everyday reality for a great part of mankind. Starvation, illiteracy, premature death, lack of adequate housing miserable living conditions are the common fate of the major part of the inhabitants of the under-developed countries. We should not wait 80 or 100 years until an eventual exhaustion of the natural resources, or pollution make the great centers of the developed countries feel their effects. Thus the priority goal should be to avoid these catastrophies. The less advanced societies cannot progress by copying the patterns of the developed countries because socio-political conditions can not be duplicated and these patterns are not desirable.

b) A destructive value system has produced the detrimental and irrational use of natural resources and the deterioration of the environment, both characteristics mainly derived from the growth of consumption of the developed nations and of the privileged minorities of the developing countries. Thus solutions to these problems cannot be found by applying corrective measures, but rather by creating a society intrinsically compatible with its environment.

c) No policy for the preservation of the ecosystem or for the reduction of consumption of natural resources can be effectively carried out at the world level until each human being has reached an acceptable level of life. This does not mean that no action is needed until this level has been reached; it does mean that policies might be successful only in the transitional stage, and to the extent that they form an integral part of those measures aimed at improving the cultural and material conditions of the submerged masses of mankind.

d) The privileged sectors of mankind -essentially those of the developed countries- must reduce their rate of economic growth in order to decrease their misuse of natural resources and the environment, and also to counteract the alienating effects of excessive consumption.

e) The developed countries should allocate part of the economic surplus to aid Third World countries in overcoming their current stagnation owing in part to past and in some cases current, exploitation of these countries.

f) The most rational method to control the accelerated growth of the population in the underdeveloped countries is to improve the general living conditions.

The model has been built around four basic assumptions:

a) The final goal pursued is an egalitarian world society, both socially and internationally. The basic principle is the acknowledgment that each human being, by the mere fact of existence has inalienable rights to the satisfaction of all basic needs- e.g., food, health, housing, education. These needs are considered basic because without an adequate level of satisfaction of each, a dignified and active participation in the human race becomes impossible; they are also considered invariant, as they apply to each human being independent of his belonging to a given culture, his origin, race, sex, and so forth.

b) While there are many other aspirations and needs, they differ qualitatively from these basic needs. The Model does not formalize them, since the mode of satisfaction of many of these varies with each society and with time; also the Model does not wish to determine them.

c) Each human being participates in full in all social decisions. This is an essential condition that prevents equality from becoming a mere material leveling.

d) The society in the Model is a "non-consumist" society, that is, a society in which consumption is not a value in itself.

The levels of satisfaction of the basic needs described in each of the various sectors of the Model should not be considered the desideratum for the future of mankind; they represent only a reasonable goal, in accord with present possibilities. Once the proposed levels are achieved, what happens to the economic surplus or how the surplus will be used will depend on the decisions taken by a society already liberated from backwardness and misery. The Model does not attempt to predict these decisions, but it is likely that they include such cultural options as increasing the leisure time, rather than an increase in the consumption of material goods.

In summary, the Model assumes that the egalitarian satisfactions of the basic needs and the participation of all individuals in the social decisions are indispensable prerequisites for full access to all higher forms of human activity. It aims at a mobilizing goal; it does not attempt to formulate a complete theory which defines either system of social organizations, or a plan pre-established for these purposes. Such a claim would be illusory, dangerous and probably impossible to substantiate. All historical progress simultaneously solves problems and generates new ones; thus posing new possibilities and challenges.

Discussion

Peter Sint, Rapporteur

Panov opened the discussion by asking several general questions. In his view, the model not only describes but also seeks to change the future. Thus he asks: to whom is the project addressed? To the governments of different countries to help policy planning? Could countries, as for example capitalist countries, alter something without the instrument of centralized planning. Even a government agreeing to the proposals in the model could not alter policy in such a revolutionary way as to yield these results. An alternative way may be to give a scientific basis to ideology if your project is addressed to the masses. Are there alternatives to the socialist (Marxist) ideology and to the capitalist ideology? Panov further questioned the reason for dividing the world on a geographic basis. Could it be that you did not find differences in the relations between capitalist and developing countries and between socialist countries and developing countries? He saw some paradoxes in this method of dividing. For example only one hundred years ago Bulgaria was liberated from Turkey after five centuries of occupation; today Bulgaria is a developed country assisting the development of Turkey. He asked whether differences had been found in the model's results and the theory of zero growth.

Herrera responded to Panov's remarks as follows. The question of to whom the model is addressed is important and I agree that it should be a means for helping policy planners. We do not intend to create an instrument for practical policy. As to how to qualify the model, he suggested that it be viewed as an utopian model; in his opinion, it is a good model. Historically there are two types of utopias. One is the Platon type of utopia, a characteristic of which is that the feelings were of the intellectuals and not those of large masses of people represented. We believe that the content of a model in some way interprets the masses of people. It shows that solutions are possible given that certain political and social changes take place. We want to destroy the image that development follows a physical or material trend, and to show that it is an open process that depends on the will of man. You ask how the government can accomplish this. We do not know the answer; it is an ideological contribution; however, we will make suggestions how the problem might be solved. For example it is shocking that the problems of two billion people can be solved with only one half the amount of money now being spent for weapons. Our model is directed at influencing the public opinion and is not an instrument for policy making.

Regarding your question about ideology and whether we have an alternative to socialism and capitalism, we think one exists and can be found in the literature on this subject. One of the difficulties is to define a system that results from historical precedence. In the description of the model we have criticized both the capitalistic and the socialistic roles in the modern world.

We are not denying that there are some factors, but there have been historical deformations of the ideals. These are ideas for the future that should be considered.

Addressing himself to the question of division, Herrera stated that there are many ways to disaggregate the world. We think that the developed countries have many things in common. As for the geographic divisions, we think that the countries located near each other have more relations than others at a distance; indicators are more homogeneous. Disaggregation is a compromise. It would probably be ideal to disaggregate by countries. However, we think that our division is the most practical, but acknowledge that others exist.

In the opinion of Scolnik, each type of division has its problems, and nations will always be found to be quite different. Many problems exist; however, we think this is a more or less natural division. Of course, one could subdivide into more blocks. The model allows many changes--flow of capital between countries, demographic function rural to urban population. The model may be viewed as a type of toy which can be played with.

Herrera noted two additional questions. One concerned the difference between capitalist and socialist countries. One needs some criteria for dividing: ours is developed and underdeveloped countries. The socialist countries have difficult situations in several respects. From the viewpoint of underdeveloped countries, the differences are not so great. Panov stated that he had not heard about socialist multinational cooperations, to which Herrera replied in a positive manner. He added that we now have a slow growth; we do not believe in zero growth.

Koopmans pointed out that the meeting does not suppose that all share the same philosophical views. The work of the group is interesting as a feasibility study for obtaining certain objectives. In his opinion, the work is a fine piece of systems analysis and world modelling, but more information about the details of how solutions follow from premises is needed. We should avoid discussion of side issues and study the connection between assumptions, objectives explicitly stated and solutions. It is also interesting to understand the philosophy leading to the assumptions. Later Curnow will make a proposal for a run of the model.

Rademaker said that he understood that the fertility is linked by some mechanisms to life expectancy and social conditions. He thought that this fertibility mechanism played a critical role in the results of the simulation, and suggested that the meeting consider why the developed countries became developed in the first place. We do not know whether the same mechanisms recognized in some countries would work to the same results in the other countries.

Scolnik noted that this question was critical in some respects. With respect to demography, there are different approaches, but there is agreement on several important factors in different countries, for example birthrate, industrial occupation. We have the same set of equations world wide. However, it is not clear whether it is possible to switch from one set of equations to another. The statistical data show that predictions could be made using data from many regions; this is sufficient reason for continuing this exercise.

Belsley observed a general tendency to maximize variates leading to a measurement sterility, which, he felt, should possibly be avoided. He made some suggestions. He was astonished to see life expectancy as a variable to be maximized which could lead to an absurd conclusion; we know that medicine can keep people alive after they are in fact dead. A slightly less absurd conclusion is: you could find elderly people who would not consider maximization of life expectancy necessarily a good objective. Thus he suggested that one define a reasonable age to achieve, and maximize the proportion of the population obtaining that age. There are other aspects that need to be considered. He also stated his objection to maximizing the population, let us say in the year 3000.

Scolnik replied that in the Forrester Meadows model, we tried to maximize population in the year 3000 only to show the unstableness of the Forrester Meadows model. The sensitivity analysis of the model showed the model's sensitivity to slight changes in the initial parameters. It is different to let the population grow above capacity in the year 3000, or to calculate the capacity in the next 100 years. The rational of life expectancy should be discussed from more than one viewpoint. It is a much better measure than GNP and he could show many examples of this. It is an indicator which is really affected by all achievements in the basic variables.

Roberts posed a technical question about design diagram in the report. He was confused by the fact that an increase in enrollment gives rise to an increase in child mortality, an increase in growth mortality and a lowering of life expectancy. Scolnik advised that this will be corrected.

McPhersons also asked a question on optimization. Since this model runs scenarios, he wondered whether the particular variations of the control variables were printed out. They may be interpreted as the political variables determining strategies. He asked whether there were any constraints concerning political feasibility of the sequence of values of the control variables.

Scolnik answered that the values are printed, and during the afternoon session, the constraints which seem to be reasonable according to experts will be discussed.

According to Ray, two factors seem to be important for the model. One is the economic factor, and economic models seem to fail very drastically nowadays. The second, Rademaker pointed out, is the population model. He expressed his doubts about its structure.

Curnow stated that he shared the values of the Bariloche group. He acknowledged his concern whether the work is robust, bearing in mind the changes which have taken place in the economic order during the last year. Since the world is interdependent and blocks are not in complete control of their possible reallocation, an optimal allocation seems most unlikely. Could one assume that the yearly reallocation is only, for example, two thirds of the allocation suggested by the optimization routine?

The Functioning of the Model and the Demographic Model

Hugo Scolnik and Luis Talavera

INTRODUCTION

In this Model, the economy is divided into five sectors: feeding; housing (habitational services); education; consumption; and capital goods.

In each block and for each instant of time t, there is a gross national product (GNP) which is divided into five product sectors, that is $SIPI_i(t)$, $i = 1,\ldots,5$, so that

$$GNP_t = SIPI_1(t) + \cdots + SIPI_5(t) \quad . \qquad (1)$$

GNP is expressed as a production function of the Cobb-Douglas type, in which it is verified that:

$$SIPI_i(t) = K_i 1 - \alpha_i(t)(L_i(t) \cdot SAL_i(t))\alpha_i \quad , \qquad (2)$$

where

$K_i(t)$ is the amount of capital of sector i at instant t;

$L_i(t)$ is the labor force of the sector; and

$SAL_i(t)$ is the salary paid by the sector for each person.

Capital and salaries are expressed in 1960 U.S. dollars. The parameters αi vary in each sector and in each block. The following equalities are met:

$$K_1(t) + \cdots + K_5(t) = K(t)$$
(total capital of the block in the year t); (3)

$$L_1(t) + \cdots + L_5(t) = L(t)$$
(total labor force of the block in the year t). (4)

Also, there is a system of relative prices $P_i(t)$ that allows a calculation to be made of the basic production of the first three sectors. These prices have an interpretation in the projective phase (usually 1960-1980), and a different interpretation in the optimization phase.

The Projective Phase

$P_1(t)$ = the price of a calorie; therefore

$$\frac{SIPI_1(t)}{P_1(t)} = \text{number of total calories produced.}$$

$P_2(t)$ = the average price of renting a standard housing unit; therefore

$$\frac{SIPI_2(t)}{P_2(t)} = \text{number of available housing units.}$$

$P_3(t)$ = the price of maintaining a person in the educational system; therefore

$$\frac{SIPI_3(t)}{P_3(t)} = \text{number of available seats in the educational system.}$$

The Optimization Phase

$P_1(t)$ is the price of a ton of fertilizer; this price includes production costs, amortization of the corresponding factory, expenses of erosion and agricultural costs,[1] thus

$$\frac{SIPI_1(t)}{P_1(t)} = \text{number of tons of fertilizers produced.}$$

By means of the subroutine FOODKP it is possible to calculate the total calories, the cereal and protein calories produced, and the new livestock and fish production, provided the following factors are known: the amount of fertilizers produced; the total

[1] For more details of costs, see G. Gallopin, "The Food Sector".

amount of land cultivated up to t; the amount of cultivated land; and the livestock and fish production at t. The resources in the agricultural sector needed in order for the production of fertilizers to increase the return or for the cultivation of new land are optimally allocated by means of linear programming.

Let us assume that: $P_2(t)$ is the price of renting a standard housing unit, and $P_3(t)$ is the price of maintaining a person in the educational system.

The prices verify:

$$P_1(t) + P_2(t) + P_5(t) = P_1(t_{opt}) + P_2(t_{opt}) + P_3(t_{opt}) \quad , \qquad (5)$$

where t_{opt} is the year in which optimization begins, and $t \geq t_{opt}$.

The capital at t + 1 is calculated as follows:

$$K\ (t + 1) = K(t) + SIPI_5(t) - \sum_{i=1}^{5} DELTA_i K_i(t) \quad , \qquad (6)$$

where the depreciation $DELTA_i$ is defined by sector and by block.

OBJECTIVES OF THE OPTIMIZATION PROCESS

Once the values of the variables at the instant t are known, the objectives are to allocate the capital, the labor force and the sectorial prices so as to maximize the life expectancy at birth of the population of a block, taking into account the following ten constraints.

Constraint 1. The proportion of capital of the investment sector with respect to total capital should not decrease more than five per one thousand of the proportion that it had at the beginning of the optimization phase. That is

$$\left(\frac{K_5}{K}\right)_{t+1} \geq 0.995 \left(\frac{K_5}{K}\right)_{t_{opt}} \quad .$$

Constraint 2.

$$(\text{agricultural population})_{t+1} \leq (\text{agricultural population})_t \quad .$$

Constraint 3.

$$P_i(t) \geq 0 \text{ for } i = 1,\ldots,3 \quad .$$

Constraint 4. The proportion of labor force used in the housing services is

$$\frac{L_2}{L}\,t \leq 8 \cdot 10^{-3} \quad .$$

Constraint 5. The daily calories per capita have an upper limit of 3,000. The food production system is regulated in such a way that it is possible to define the excess calories as follows:

$$\text{EXCAL} = \frac{\text{SIPI}_1}{365\ P_1(t)\text{POP}(t)} - 3000$$

where POP is the population. Once a sufficient production is achieved, one may verify:

$$100 \geq \text{EXCAL} \geq 50 \quad .$$

This allows for a maintenance of a food reserve; simultaneously, when EXCAL < 50, the mechanism of optimization notes the need to increase production before the real consumption falls below 3,000 calories.

Constraint 6. The new price of education may vary not more than four percent of the value of the previous year since, by means of the equation (5), $P_3(t)$, is eliminated as an independent variable. There is a need then to control its value since variations of one percent in the other prices may affect $P_3(t)$ considerably,

$$/P_3\ (t+1) - P_3(t)/ \leq 0.04\ P_3(t) \quad .$$

Constraint 7. This constraint does not allow the proportion of GNP assigned to consumption to decrease more than one percent in relation to the original value.

$$\left(\frac{\text{SIPI}_4}{\text{GNP}}\right)_{t+1} \geq 0.99 \left(\frac{\text{SIPI}_4}{\text{GNP}}\right)_{t_{opt}} \quad .$$

Constraint 8. Given that a system of weights is used to determine that the former constraint may be violated in cases of absolute necessity,

$$\left(\frac{SIPI_4}{GNP}\right)_{t+1} \geq 0.42$$

is introduced as an absolute constraint in the sense that its weight does not allow it ever to be violated.

Constraint 9. The difference relative to the desired objective may be defined as follows:

$$A(t) = \frac{3000 - CALORIES(t)}{3000} \quad , \text{ where } CALORIES(t) = \frac{SIPI_1(t)}{365\ P_1(t)\ POP(t)} \quad ;$$

$$B(t) = \frac{98 - ENROLL(t)}{98} \quad , \quad \text{where } ENROLL(t) = \frac{SIPI_3(t)}{P_3(t) POP_{5-17}(t)} \quad .$$

The constraint

$$/A(t) - B(t)/ \leq 0.1/A(t_{opt}) - B(t_{opt})/$$

is included for any t. This requires that the growth or the decrease of the calories as well as enrollment be realized in a coordinated manner.

Constraint 10. The following constraint does not allow enrollment to grow more than ten percent annually:

$$ENROLL\ (t+1) \leq 1.1\ ENROLL(t) \quad .$$

We have assumed in this Model that an economic development plan is socially acceptable provided that each person perceives that the level of satisfaction of each of his basic needs has not decreased. This criterion is introduced in the three following constraints:

Constraint 11.

$$CALORIES(t+1) \geq CALORIES(t) \quad ;$$

Constraint 12.

$$HOUXFL(t+1+ \geq HOUXFL(t) \quad ,$$

where HOUXFL is the number of housing units per family; and

Constraint 13.

$$ENROLL(t+1) \geq ENROLL(t) \quad .$$

The following six constraints are also taken into consideration in the model:

Constraint 14. The price of the housing unit must be decreasing, except when it is absolutely necessary to increase it, as for instance, in the case of low food production. That is,

$$P_2(t+1) \leq P_2(t) \quad .$$

Constraint 15. The following constraint is fundamental:

$$LE(t+1) \geq LE(t) \quad ,$$

where LE is the life expectancy at birth.

Constraint 16. If all the basic needs are not satisfied, then increasing the proportion of the GNP assigned to consumption is not allowed, so that:

$$\left(\frac{SIPI_4}{GNP}\right)_{t+1} \leq \left(\frac{SIPI_4}{GNP}\right)_t \quad ,$$

if EXCAL < 50, or HOUXFL < 1, or ENROLL < 98.

Constraint 17. If all the basic needs are satisfied, then AI = 0.15 and, AI = 0.21, otherwise. Hence:

$$0.25 > \left(\frac{SIPI_5}{GNP}\right)_{t+1} > AI \quad .$$

Once the basic objectives are achieved, this constraint makes it possible to go to a non-consumer economy, maintaining a growth in accord with population growth, that is, with a small growth per capita.

Constraint 18. Given that the most costly problem is that of housing and that the optimization phase by nature gives priority to the food and education sectors, a penalty function is introduced in the form:

$$-W_{13}\ \mathrm{MIN}(0,\ \mathrm{HOUXFL}\ -1) \quad ;$$

this acts only when EXCAL > 50 and ENROLL $\geq$ 98.

Constraint 19. The consumption sector is given priority once satisfaction of the basic needs is achieved. This fact should be interpreted in terms of an improvement in the quality of life through better housing, improvements in the quality of education, in the environment and the like, and other factors of a cultural nature. Thus one defines:

$$\mathrm{QLIFE} = \frac{\mathrm{SIPI}_4}{\mathrm{GNP}}$$

when EXCAL > 50, HOUXFL $\geq$ 1 and ENROLL $\geq$ 98; and QLIFE = 0 otherwise. The objective function to minimize is

$$f = -(1 + \mathrm{QLIFE})\mathrm{LE} \quad ,$$

subject to the aforementioned constraints.

There exists a set of additional constraints on the independent variables that are dealt with directly by means of the following trigonometric transformations:

a) The distribution of the labor force among the sectors can vary annually up to two percent. (These limits are never reached for numerical reasons.)

b) The distribution of capital can vary annually up to six percent. (These limits are never reached for numerical reasons.)

c) The prices P_1 and P_2 can vary only one percent. (These limits are never reached for numerical reasons.)

MATHEMATICAL METHODOLOGY

An optimal control problem that describes the time evolution of the variables $x_1(t),\ldots,x_n(t)$ may be stated in the form:

$$x_1(t+1) = f_1^t(x_1(t),\ldots,x_n(t),\ v_1(t),\ldots,v_r(t))$$

$$\vdots$$

$$x_n(t+1) = f_n^t(x_1(t),\ldots,x_n(t),\ v_1(t),\ldots,v_r(t))$$

$$x_i(0) = x_i^o \quad , \quad i = 1,\ldots,n \quad ,$$

where $x_1,\ldots x_n$ are the state parameters, and $v_1,\ldots,v_r$ are the control parameters; f_i^t is used to indicate that eventually the functions f_i may change with t. The former system corresponds to the discretization of the system of differential equations

$$\dot{x}_i = f_i^t(x_1(t),\ldots,x_n(t),\ \ v_1(t),\ldots,v_r(t)) \quad ,$$

with the initial conditions $x_i(0) = x_i^o$.

The classical problem of control requires that the function $v(t) = (v_1(t),\ldots,v_r(t))$, defined for $0 \leq t \leq T$, take values in a closed region V. That is, $v(t) \in V(t)$. The objective is to determine a control $v^*(t)$ for which a certain function takes an extreme value. For control processes described by systems of ordinary differential equations, there exists the fundamental principle of the maximum of L.S.P. Pontryagin which allows one to decide when a certain control is optimal. When a digital computer is used, the differential equations must be replaced by difference equations in such a way that the original problem is solved as a finite dimensional mathematical programming problem (see, for instance, [8,9,10]).

The usual computational techniques for control problems assume that one has the functions f_i, or at least the corresponding approximations in differences.

The present model is complex since the output of the system is obtained through the interaction of many non-linear functions, with multiple feedbacks, and some intermediate values are obtained implying secondary processes of optimization (for example, by linear programming in the Food Sector). Thus it is almost impossible to make explicit the analytic form of the functions f_i, and even less so their partial derivatives.

The technique used in this Model has its origins in the study of sensibility of the World Three Model developed by Meadows et al. The usual methodology consists in varying one parameter at a time, running the Model, and observing how the results change.

Mathematically, this is equivalent to assuming that a function of n variables can only change along the coordinate axes. For example, if one has the "model"

$$z = \frac{xy}{(x-\varepsilon) + (y-\varepsilon)} \quad ,$$

and the initial point is $(x_o, y_o) = (o,o)$, by taking increments of one variable at a time, one obtains:

$$z(d_1,o) = z(o, d_2) = o \text{ for all } d_1, d_2 \quad .$$

According to the classic analysis of sensibility, such as that used by Meadows, this model would be totally stable; however, it has a pole in $(\varepsilon,\varepsilon)$. In Scolnik [27], the population given by the World Three Model in the year 3000 was taken as objective function, and its partial derivatives with respect to the initial parameters (which have a margin of error) were calculated. By moving along the gradient in such a way that it did not affect an initial value more than five percent, the result obtained was that the population grew, without being affected by any catastrophe, beyond the year 2300.

The idea of calculating partial numerical derivatives of a complex system arises where problems of automatic control are posed, as for instance, when one wishes to correct disturbances in the functioning of industrial plants [18]. However, it appears that the methodology applied in the Bariloche Model is new; a description of the methodology is given below.

The problem of maximizing life expectancy (subject to the constraints mentioned above) is a particular case of the general problem of non-linear programming:

$$\text{MIN } f(x_1,\ldots,x_n) \quad ,$$

subject to

$$g_i(x_1,\ldots,x_n) \geq o \quad , \; i = 1,\ldots,j \quad ,$$

$$h_i(x_i,\ldots,x_n) = o \quad , \; i = 1,\ldots,P \quad .$$

For this general problem, there exist several techniques such as the one developed by Fiacco-McCormick [14]. Given $(x_1^o,\ldots,x_n^o)$ such that $g_i(x_i^o,\ldots,x_n^o) \geq o$ for $i = 1,\ldots,j$, the function:

$$F(x,r_k) = f(x_1,\ldots,x_n) - r_k \sum_{i-1} \ln g_i(x_1,\ldots,x_n)$$

$$+ \frac{1}{r_k^2} \sum_{i=1}^{P} h_i^2(x_1,\ldots,x_n)$$

is minimized. Under certain conditions, the succession of minimums of the unconstrained function F converges to the solution of the problem when $r_k = 0$. The disadvantage of the method is that it is necessary to minimize F repeatedly, and that the control of the step in a method such as that which Fletcher and Powell [11] used to find the minimum often leads to serious numerical problems.

Carroll's method [4] is applied where there are no equalities, through the successive minimization of:

$$F(x,r_k) = (x_1,\ldots,x_n) + \frac{1}{r_k} \sum_{i=1}^{j} \frac{1}{g_i^2(x_i,\ldots,x_n)} \quad .$$

These processes may be often accelerated (see Fiacco-McCormick [14], Fletcher-McCann [12]). More details on this subject can be found, for example, in Himmelblau [20]. In recent years various methods have been developed to achieve the construction of penalty functions as for example, that their unconstrained minimum coincides with the solution of the original problem. Thus, one should mention, among others, works by Fletcher and Lill [13], and Conn and Pietrzykowsky [5]. We must solve the problem by means of derivative-free algorithms, taking into account that each evaluation of the function and of the constraints requires running the model from t to t + 1.

At present, the most efficient methods employed to minimize functions, without calculating derivatives, are the following: a) Powell's method [22]; b) Brent's modification of Powell's algorithm [3]; c) Stewart's modification of the variable metric procedure [28]; and d) the version without derivatives of the modification by Gill and Murray of Fletcher and Powell's algorithm [15]. Other methods are known (for example, Cullum [6]) but there is not as yet sufficient experience with them.

For problems in which the estimate of the gradient is not very precise, owing to the nature of the problem and/or to the accumulation of round-off error, methods a) and b) above provide improved results (Cullum [7]). As a result of this, as well as of the numerical experience known (Brent [3, pp. 137-155]), we have preferred the use of Powell's algorithm, in the version available in the library of Programs of Stanford University. Although Brent's PRAXIS method, in general, requires less iterations and therefore less evaluations of the function, the complexity of computing involved is greater. Thus far, PRAXIS has not been tested in the Model because of memory limitations; but the numerical experiences will be included in the final report. A possible advantage of PRAXIS would be its capacity to extrapolate along valleys, which appear to be constrained problems. Analogously, Gill's and Murray's algorithm [15] will be tested.

In the Bariloche Model we cannot use interior points techniques because the region $G = \{x/g_i(x) \geq o\}$ may be empty. In other words, there are cases in which no possible combination of capital, labor force and prices exists that satisfies all of the constraints. Only the following equalities:

$$h_i(x_1, \ldots, x_n) = o$$

(see equations (3), (4), and (5)) which, since they are linear, allow one to eliminate three variables.

Our objective function is:

$$F = -(1 + QLIFE)LE + \sum_i W_i MIN^2 (0, g_i(x)) \quad ,$$

where the weights have been carefully chosen in such a way that, if it is not feasible to satisfy all of the constraints, the process of optimization may elect to violate the less relevant constraints; this must be done within a certain established order, details of which may be seen in the program.

After the optimization method has been applied, one should control whether the function F is negative in the minimum. If it is negative, there are no violated constraints (which is true when OLIFE = 0); in this case, the process is terminated. If the function is positive, one should randomly alter the result obtained; and the optimization is then repeated a specified number of times (Powell [23, p. 341]) controlling whether the process converges to the same point or not.

Once the point giving the minimum value of the function has been determined (among all of the trials carried out, although there is not always convergence), the Model from t to t + 1 is run with these values in order to calculate the values of all of the variables; therefore the whole procedure is repeated for the next year.

It is worth noting that to apply this methodology, computational experience in these kinds of problems is needed so as to be able to overcome the numerical problems that often arise.

THE ADJUSTMENT OF THE BARILOCHE MODEL IN THE 1960-1970 DECADE

A necessary although not sufficient condition to establish the validity of a model is that it should allow one to reproduce reasonably well a certain historical period. This Model begins with the year 1960 (a date for which data exist on the basic variables, capital and labor force by sectors, sectorial and total gross product, calories consumed, educational levels, and so forth). We also have these data for 1970.

From the relation:

$$SIPI_i = K_i^{1-\alpha_i} \; (L_i SAL_i)^{\alpha_i} \quad ,$$

it follows that, given $SIPI_i$, K_i, L_i, and α_i, one can deduce the SAL_i (average salary of the sector), a value that is not known a priori with precision. Since on the α_i's values various estimates exist in literature, we have chosen to adjust the values of α_i and of $SIPI_i$ by means of an optimization process. For this purpose, we minimized the following function:

$$f(\alpha_i, SIPI_j) = \sum_K WK \; \frac{Y_k - Y_k^C}{Y_k} \;\; 2$$

where Y_k is the measured value of the variable in 1970; Y_k^C is the value predicted by the Model; and W_k is a system of weights that varies with the error of prediction (in percent).

This function was minimized by Powell's method, and each evaluation of it is run by the Model from 1960 to 1970. In addition, constraints on the variables were included. Starting data are derived from sources cited in the report of the Economy Sector. Convergence was obtained in all the blocks, and we obtained the results as shown in Table 1. Note that the prediction of the GNP per capita in blocks 2, 3, and 4 is systematically low; on the contrary, the prediction for housing per family is high for all the sectors. Gross mortality is highly underestimated in block 1 apparently because the regressions were calculated using data from 121 countries, most of which lack an adequate degree of development in their basic indicators. Therefore, in block 1, the function of gross mortality exaggerates the effect of feeding, housing, and so forth, on this variable.

Table 1.

	BLOCK 1 Europe		BLOCK 2 Latin America		BLOCK 3 Africa		BLOCK 4 Asia	
Variable	Real Value	Predicted Value	Real Value	Predicted Value	Real Value	Predicted Value	Real Value	Predicted Value
GNP	2,028.0	2,048	444.0	409.0	167.0	149.0	113.0	88.0
Population	$0.105.10^{10}$	$0.109.10^{10}$	$0.277.10^{9}$	$0.270.10^{9}$	$0.296.10^{9}$	$0.302.10^{9}$	$0.198.10^{10}$	$0.202.10^{10}$
Gross Mortality	9.2	6.45	9.1	11.2	20.6	17.3	15.5	14.9
Children Mortality	23.0	25.0	74.0	68.0	94.0	115.0	124.0	96.5
House Rate	24.5	30.3	9.8	10.5	8.8	10.7	8.9	9.2
Calories	3,000.0	3,000.0	2,472.0	2,497.0	2,273.0	2,312.0	2,057.0	2,042.0
Enrollment	97.5	98.0	60.0	60.2	28.3	28.0	0	50.5
Birth Rate	17.5	15.9	38.0	37.5	45.7	44.7	38.5	41.9
Life Expectancy	70.0	72.6	61.8	58.9	42.6	46.3	50.0	52.5

DESCRIPTION OF THE METHODOLOGY USED TO OBTAIN THE FUNCTIONS OF THE SUBMODEL ON DEMOGRAPHY AND HEALTH

The existing models that calculate demographic variables such as mortality rates and age structure, require in an exogenous way rates of fecundity, life expectancy, and so forth. To overcome these approaches (which are not useful for the purposes of this Model), an extense multivariate analysis was carried out to obtain regression models that would allow one to achieve a good numerical prediction. A data bank was formed using various sources (for example, the United Nations Statistical Office, the International Labour Organisation), and an automatic system was designed to study the functional relationships among them. It should be noted that given the high degree of correlation among many of the variables, the ordinary regression techniques failed since the resulting systems are very unstable. The best numerical methods of regression are a) Golub's method [17] which uses Householder transformations; b) the modified Gram-Schmidt's method [1]; and c) the singular value decomposition algorithm [16]. Algorithm a) above requires that the matrix be full-rank. Method c) above provides the solution to minimum norm when the matrix has deficient rank. The most effective method is to simplify the model in the case of incomplete rank by means of the calculation of a basic solution. Since methods a) and b) above are equivalent in the full-rank case [2], and if one formally defines [2], a process of orthogonalization takes place by means of the following: Given

$$a_1, \ldots, a_n \in R^m \quad , \; n \leq m \quad ,$$

compute

$$e_1 = \frac{a_1}{//a_1//} \quad \text{if } //a_1// \neq 0 \quad ;$$

otherwise $e_1 = 0$.

$$e_1' = a_i - \sum_{j=1}^{i-1} < a_i, e_j > e_j \quad ,$$

$$e_i = \frac{e_i'}{//e_i'//} \text{ if } //e_i'// \neq 0 \quad ;$$

otherwise $e_i = 0$, for $i = 1, \ldots, n$ is carried out with the method MGS with accumulation of inner products in double precision. The advantage of these algorithms is that they avoid forming explicitly the matrix A^tA, and therefore do not square the condition number of the system. (This is the reason why the traditional methods fail in problems such as this.)

Non-linear regressions have also been tried, using the technique of variable projections [26], [21], [19], without finding as yet a functional form that improves the lineal fitting.

The regressions have been carried out for all the countries from the data bank as a whole. The adjustment by blocks was discarded since later it would not be clear how and when to switch from a functional form to another in accordance with the level of development of the unit considered. The advantage of having unique functions is that they can be used to predict the numerical values of the variables in countries with highly different degrees of development.

In this work functional relations are not confounded with causal ones. We have attempted to express the demographic variables as functions of the socio-economic indicators that different studies consider relevant. The results obtained are as follows:

$$LE = 0.057\ PR - 0.15\ AGP + 0.25\ SEP + 0.27\ EN + 0.013\ HR + 39.135,$$

$$CHM = -0.16\ PR + 1.06\ AGP - 0.275\ SEP - 0.92\ EN + 118.94,$$

$$BHR = -0.74 \cdot 10^{-3} CC - 0.05\ PR - 0.11\ SEP - 0.06\ EN - 0.32\ LE - 0.65\ HR + 72.57,$$

$$GRM = -0.64 \cdot 10^{-3} CC - 0.003\ PR - 0.075\ BHR - 0.31\ LE + 0.04\ AGP + 0.04\ CHM + 30.368,$$

$$PF = 0.023\ BHR - 0.08\ GRM - 0.001\ CHM - 0.009\ UR - 0.06\ HR + 5.976,$$

$$PO9 = 0.37\ BHR + 0.09\ LE - 0.23\ GRM - 0.04\ PR - 0.42\ SEP + 17.715,$$

$$P1014 = -0.2 \cdot 10^{-3} TC - 0.3610^{-3} CC + 0.07\ BHR + 0.02\ LE - 0.05\ GRM - 0.13\ SEP + 10.29,$$

$$P1519 = -0.59 \cdot 10^{-3} TC - 0.42 \cdot 10^{-3} CC + 0.02\ BHR - 0.02\ GRM - 0.1\ SEP - 0.01\ HR + 12.06;$$

where

LE = life expectancy,

AGP = agricultural population,

SEP = secondary population,

EN = enrollment,

HR	=	house rate,
CHM	=	children mortality,
BHR	=	birth rate,
CC	=	calories from cereals and starchy roots,
PF	=	persons per family,
UR	=	urbanization,
P09	=	population between 0 and 9 years old,
P1014	=	population between 10 and 14 years old,
P1519	=	population between 15 and 19 years old.

The correlation coefficients corresponding to the eight fittings are

Life expectancy	0.937,
Natality	0.914,
Children mortality	0.801,
Gross mortality	0.814,
Persons per family	0.751,
Population 0 - 9 years	0.929,
Population 10-14 years	0.861,
Population 15-19 years	0.857.

The population between 6 and 17 years old required by the education sector is obtained by linear interpolation using the previous values.

It is feasible to explain the dependent variables using different combinations of the other variables with approximately equal numerical results. For instance, some demographers prefer to explain the birth rate as a function of mortality. (Relationships between the demographic change and the economical development as given by the 1974 United Nations World Conference on Population are among other variables.)

Here, we will not give the results of the usual statistical tests for the following reasons: given the system Ax = b with $A_{M \times N}$, $M \leq N$ a full rank matrix, the least squares solution is the one which minimizes $||Ax-b||^2_2$. Let us assume that x is the correct solution and $\hat{x}$ a computed one. It is easy to show that:

$$\frac{//r//}{G_1} \leq //x - \hat{x}// \leq \frac{//r//}{G_n} \quad ,$$

where $r = b - A_x$ is the residual vector, and G_1 and G_2 are respectively the highest and lowest singular values of A. It is not difficult to give examples where $||r||$ is very "small" and $||x-\hat{x}||$ is "large". In the usual statistical tests it is implicitly accepted that x = x, which is in general completely false. Even when using stable numerical methods for computing the singular values, it is common to see that the inequalities 1 are not satisfied because of the round-off error. What one is really looking for is an estimation of the real statistical parameters x; but it makes no sense to apply blindly a test to $\hat{x}$ without knowing how it differs from x. It is often feasible to obtain high precision results using the iterative refinement; however this is not always possible or desirable for a statistical test since seeking the minimization of $||r||_2^2$ may lead to a deviation from the true values because of truncation error [25]. These problems are usually ignored in practice, but are essential where dealing with a highly correlated model.

In the future, we shall try to explain fecundity by means of these techniques for using a more detailed demographic model developed at CELADE which needs this variable and expectancy of life at birth as exogenous variables.

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Urbanization and Housing

Diana Mossovich

URBANIZATION

The world's population is experiencing an accelerated process of natural growth. This ecological-demographic trend, interacting with other social aspects, results in a swelling of the urban population and an increase in internal migrations. Projections for the world's population for the year 2000 are 6,112 million inhabitants; 79.28 percent will live in the economically less developed regions, and 20.72 percent in the economically more developed ones. According to these projections, the world's urban population will then be 3,090 million, which is 50.55 percent of the total world population. Of this projected urban population 67.32 percent will be located in the economically less developed regions, whereas 32.69 percent will be in the more developed regions. In 1970, the world's population was predominantly rural, and it is envisaged that it will continue to be so until the end of the twentieth century. However, between 1970 and 2000, 67.85 percent of the growth in the world population will occur in urban areas.

These facts indicate that, although there will be a spacial shift of the population from one rural area to another, the population will predominantly concentrate in urban centers.

Rather than offering a detailed description of a situation, these projections and estimates predict the population's spacial distribution trends on a worldwide scale. Man will not only have to construct and manage growing numbers of urban agglomerations of sizes unheard of by mankind; he will also have to solve a multiplicity of economic, social, environmental, technological and political problems.

In addition, 77.27 percent of the projected urban growth between 1970 and 2000 will take place in the less developed regions, that is, in those regions less endowed with investment resources.

The impact of migrations, within and among countries, has grown and will continue to grow, although its real value is difficult to assess. The main cause for the rapic urbanization worldwide, especially as experienced in countries in the economically less developed regions, is the high growth rates of the urban population. As these growth rates increase so will their impact on the urbanization process within each country.

At this point, we would like to define "urban population," "rural population," and "urbanization".

Since we have dealt primarily with data found in United Nations publications, we have adopted the definitions as used by the UN. However, a human urban settlement can be an agglomeration of several thousands of inhabitants as well as a center of a few hundred. According to some definitions, "rural population" may include a farmer in the USA, Canada or West Germany, as well as an arab nomad.

"Urbanization" is the concentration of population, facilities, and productive investments in certain sections of a territory. It is a worldwide process, offering a varied intensity in different regions. A comparison of urban growth rates in the regions and countries worldwide for 1970 shows that the countries with the highest annual rates of urban growth are predominantly rural; 65 percent of the overall population. Conversely, countries with lower annual rates of urban growth are already predominantly urban, with less than 25 percent of their national population considered rural, and an annual growth rate of the national population below one percent. It can also be seen that the economies of many countries have been unable to create jobs and to provide the minimum standards of living for the rural population and for the population emigrating to the cities. The world urbanization process is growing at an annual average rate of 3.17 percent, although in some 37 countries the rate is over 4.55 percent--50 percent more than the world average. These sobering figures make us question whether it is desirable to accelerate the urbanization process in the light of present trends which indicate that between 1970 and 2000, 1,760 million people, or an annual average of 58.6 million people will be located in existing cities or in those that will be created between this period. Is it better to maintain the actual urbanization rate or even to try to reduce it, particularly in those regions where the creation and construction of basic urban life conditions will take longer and demand unusual efforts? What spacial structure is more convenient in order to make the best use of natural and human resources, and technology within a region?

Under present economic and socio-political conditions, the growth of the urban population is closely related to the growth of the rural population. Town and country must be socially and economically considered as an integrated space, with connecting productive activities and facilities. We can no longer continue to think of separate urban and rural problems, but of political, economic, social and technical problems to be solved simultaneously. Under the present conditions, the lack of integration of rural and urban economies and societies is the greatest drawback to problem solving.

As for the rural population, we believe it would be difficult, perhaps impossible, to provide rural inhabitants with an adequate living standard, permanent jobs, housing, sanitary and health facilities, if they live in isolation. The settlement patterns that the rural population will adopt in the world's regions and the size and characteristic of these settlements depend on many factors, including the ecosystems, the agricultural productive system (e.g. the land tenure system and technology), the commercial system of agricultural production, and the society's cultural characteristics.

What special structure in each region and country can best serve the aim of integrating rural and urban societies in their political, economic and technological aspects, while maximizing productive investments and investments in social services, thereby allowing for an improved exploitation of natural resources and a more reasonable use of human resources?

There is a strong relation between a region's productive system and its spacial structure. Since the productive system is determined by the use that the socio-political system makes of the region's resources, the socio-political system is the determining factor in the overall spacial structure in the urban-regional system.

The world's population tends to concentrate in certain sections of a country, building greater populated and extended agglomerations. Population has also tended to concentrate in rural areas dedicated to intensive farming. If actual trends continue, the increase in the population concentrated in agglomerations of over 12.5 million inhabitants and in agglomerations of between 2.5 and 12.5 million inhabitants will be greater than that in any other scale of agglomeration.

Urbanization, as already stated, is the concentration of productive investment, population and facilities in certain sections of a territory. This means that the process of urbanization cannot occur in complete isolation. Certain preconditions are needed for it to take place, to evolve and to become integrated into a system. Among these preconditions are the following: the backing of a rural or an industrial economy; transportation and communications systems interconnecting a center with other points of the system and with other neighboring productive areas; a population in need of social services and facilities; and comparatively low production and transportation costs. This process, in most cases, has taken place in a spontaneous way. Or rather, we might say that the factors actually determining the transportation and communications systems, the cities' functions, and the localization of social services are the political influences of the groups in power.

HOUSING

Although a lack of reliable statistics is a serious drawback, the data available allow us to estimate that about 50 to 60 percent of the world's population, especially in the economically less developed regions, lives in poorly built and equipped houses, and in unsatisfactory environmental conditions. This estimation includes the urban as well as the rural population.

As a result of the accelerated urban population growth occurring in most countries of Asia, Africa and Latin America, the housing and environmental problem has reached a critical point.

It is universally accepted that a proper housing unit is essential for the physical and mental health of the population, and favorably affects public health programs by reducing costs. A proper housing unit may increase the productivity of hand labor, help maintain healthy family links, and raise the population's spiritual level. The way a population is housed is a meaningful expression of its social and economic progress. Proper housing unit, with its complementary facilities, is a basic element for providing the population with adequate living standards, as well as an important part in the formation of a country's capital, because housing contributes to the creation of jobs directly by means of the building industry and, indirectly, through auxiliary industries and activities.

There is no accurate knowledge of how serious the housing shortage is or of what the housing production rate is at the worldwide or the regional level. There is no information as to the investment needed to provide each rural and urban family with a proper house and its basic complementary facilities. Few governments have housing and public service programs that take into account the housing resulting from the population's natural growth while simultaneously allowing for a solution to the problems of shortages of new dwellings and inadequate obsolete dwellings. Few governments have established guidelines, adjusted to climatic needs for the size of the unit, the existence of construction materials and capital availability of a housing program.

Each projection regarding future housing needs is usually based on three factors: a) requirements arising from the need to overcome existing shortages because there are homeless sectors of the population, or because the population is very poorly housed; b) requirements arising from the growth of the population, including migrations; c) needs originating in the periodic loss of houses because of destruction or because they are considered uninhabitable and cannot be improved.

Estimates of the existing housing shortage are made on the basis of estimates of volume of constructed units needed to eliminate deficiencies in the housing sector. These deficiencies can range from construction of a new housing unit, to the enlargement of a house in order to reduce overcrowding.

To summarize, to evaluate a country's housing shortage we must bear in mind: a) absolute housing shortage is almost nonexistent--there are degrees of deficiency in the housing situation; and b) a housing unit's "useful life" is not the same in all countries, but some general criteria are needed to determine the replacement rate. The loss of housing units and their replacement should be considered in housing programs.

In general terms, available information for the three variables we have chosen to diagnose the housing sector's situation--shortage, production and costs--is so poor for Asia, Africa and Latin America that we are tempted to say it has little relevance. Since existing data are relatively recent, proper analysis of the evolution of any of the three variables is not possible. Better quality information exists for Europe and for other developed regions.

Houses in rural areas are inadequate in general terms or have serious deficiencies. They are mostly built by their own inhabitants, in some cases, with the help of the community. Handicraft techniques and the use of local materials prevail. Urban dwellings offer a greater uniformity as a result of the use of manufactured materials and the existence of building codes and rules.

A great difference between rural and urban areas is owing to the existence of an organized building industry in the urban area; this means that there exists professionals, firm managers, and all types of technicians. There is a lack of skilled individuals in rural areas.

In general, the housing shortage varies from one area to the other. However, two well defined groups can be identified: the economically more developed countries where the shortage amounts to eight percent in scattered developed countries, and six percent in Europe; and the economically less developed countries. The shortage for Latin America and the Caribbean, Africa and Asia is 40 percent, 60 percent and 50 percent, respectively. These data should be handled with care since we do not know the methods and standards by which they were obtained.

The cost of a built square meter includes the following basic items:

a) <u>Direct costs</u>--land value, urbanization works' costs, building costs, hand labor and building materials.

b) <u>Indirect costs of a public nature</u>--real state income taxes, taxes on facilities, taxes on buildings, interest on credit, and others.

c) <u>Indirect costs of a private nature</u>--professional fees, insurance, contractor's earnings, interest on the firm's capital, machinery and equipment depreciation, and others.

Costs vary from one city to the other, and even within the same country, and according to the type of housing unit. There is usually a lack of rules for building housing units.

The effect of the cost of land on the total value of a housing unit is difficult to determine. There are great variations from country to country, and within regions in a country and even within a city. In some countries land costs represent 50 percent of the total cost of a house.

In 1970, in economically less developed countries, hand labor costs were between 25 percent and 35 percent of the built square meter, construction materials amounted to about 50 percent to 60 percent and management costs and taxes each to about 10 percent to 15 percent.

In general, during the last decades construction costs have increased faster than general prices of goods and services, partly because dwellings built over the last few years are larger, and have better quality equipment, finishings and construction. Another reason has been the growing hand labor costs in many countries. This trend can be observed equally in the more developed countries and the less economically developed countries. Costs tend to be higher as the per capita income is greater, possibly as a consequence of higher construction standards and the greater influence of salaries.

One-family houses are the cheaper in most countries, in particular in the less developed countries than are five- to eight-story multi-family buildings, because the latter require elevators, mechanical furnishings, and the like. This is also true of nine- to twelve-story buildings. Ten- to twelve-story multi-family buildings are 30 percent more expensive than ground buildings. These general considerations vary from one country to another and also depend on the technical specifications and applied standards. In general, the cost of a built square meter for the lower cost housing type (that is, one-family unit without land and facilities in economically less developed regions), is between US$ 30 and US$ 35, and in the economically more developed regions between US$ 70 and US$ 80. There is no universally accepted method for comparing costs.

Apparently, the best way of reducing costs in the economically less developed countries lies in organizing the production of building materials. The cost of building materials must and can be reduced, although we do not know to what percentage.

We have set the price of the built square meter in the economically less developed regions (Asia, Africa and Latin America) at US$ 35. Although this figure is below the real minimum value for the greater part of these countries, we have selected it to facilitate the working out of the needed investment. It roughly incorporates variations due to climate, ecology, available materials, etc. This cost has been accepted by many international institutions and experts who are familiar with the situation in the countries of these regions. We have used the same system for determining a dwelling of 50 square meters for a family of 4.5 to 5.5 members, allowing for two bedrooms, a living room, a kitchen-dining room, and sanitary facilities. The total cost of a house of this type would be as follows:

Construction costs: 78 percent of which 32 percent was for hand labor, and 46 percent for building materials.

Facilities: 10 percent of the total cost. (This includes connections to main running water, electricity, sewage drainage line, street pavement and rain drainage.)

Indirect costs: 12 percent of the total cost.

Our model assumes land is without cost. Urban and suburban land are socialized. As for the economically more developed countries, the price of the built square meter has been set at US$ 98. The breakdown of this cost is similar to that for the economically less developed countries, although a greater percentage is needed for construction materials and facilities' costs.

Some governments have tried alternative solutions to uncontrolled settlements. The cost of these alternative solutions varies, but, depending on the country and on the particular situation, it can range from 10 percent of the cost of the basic housing unit (if a "land and facilities" program is adopted) to 20 percent (if the same program is considered) plus sanitary units and connections, ground slab and basic structure. As we have estimated the cost of a complete house is US$ 1,750; this means the costs proposed vary from US$ 175 to US$ 350 for each housing unit in these programs.

There are no precise data regarding the importance of the population living in uncontrolled settlements in terms of the total population of a city or country. Uncontrolled settlements are not a feature of our times; but their importance today turns them into an outstanding problem. Their actual relevance is due to the rapid urban population growth and to the inability of governments to create jobs, housing and facilities in the amounts needed. Therefore, the urban population searches for solutions on its own, in the best way at hand. Many governments still consider uncontrolled settlements as temporary situations. Others have tried to eliminate them, often employing coercive measures, as if this method (which excludes the possibility of solving the structural causes of uncontrolled settlements) were really effective. Statistical evidence shows there is a strong relation between the growth of uncontrolled settlements and the socio-economic situation of each region. Living standards in uncontrolled and squatter settlements are far from those stated by the governments of each country. As a result of a lack of running water and sewage systems, or the minimum health requirements, child mortality, aggravated by malnutrition and disease, should be very high.

Unemployment and disguised unemployment are serious problems in both the less and the more developed countries. The building industry offers great possibilities for absorbing unemployed hand labor, and as a means of training hand labor if house building and furnishing urban facilities can be raised to essential levels.

There is sufficient evidence to show that the building industry's productivity, although in fact low, can be rapidly improved.

TRANSITION - A STRATEGY TOWARDS FUTURE URBANIZATION

It is difficult to predict what is the best way of creating conditions that will gradually allow mankind to live in agglomerations of a certain size.

Regardless of the success that governments, individuals or groups will have in promoting economic growth and social development, the population's future spacial distribution will continue to be rigidly bound within national limits. Although the development of regional systems will inevitably lead to the population's greater spacial mobility, we can nevertheless expect serious limitations as regards its spacial distribution, since national aims and resources are oriented toward the satisfaction of internal needs and the endurance of external pressures. Countries regionally grouped will tend to define policies of population spacial distribution according to the localization of productive investments, agricultural development programs, localization of social services, and transportation and communications networks. Often seeming or real national advantages may be sacrificed in the search for a better system of centers and networks that may best suit a larger scale and territorial size that renders greater national profits. During the next generation, it does not seem possible, or even desirable, to prevent the growth of cities of over one million inhabitants in those less developed regions actually lacking this size of agglomeration. As a result of the urban population's high growth rate prevailing in these regions (a growth rate that will be hard to control in the next few years), the growth rate of intermediate-sized centers should be accelerated. The impulse of intermediate cities and of rural centers with a population above 15,000-20,000 inhabitants seems to be the best way to balance the growth of the great cities.

We believe that the task of providing housing, jobs, facilities and public services to several hundred millions of inhabitants every ten years should be faced with flexibility, on an experimental basis, and with a deep respect for the cultural values of the different human groups. The question in each case is what community characteristics; including the design of the housing unit, densities, facilities, jobs, private and public institutions--should be achieved so that the inhabitants attain the best possible quality of life.

We have assumed urban and suburban land are social property. In other words, land is considered a resource belonging to society, and not an individually-owned good whose value is fixed by market fluctuations. This assumption has a double effect: on one hand, the cost of land will have no bearing on the total cost of the housing unit; on the other hand, it eliminates speculation. Speculation with land actually leads to unnecessary land-plot divisons and consequent high construction and facilities' costs.

People will no longer live in isolation. The population will settle in different scales of centers, where services, facilities and social opportunity will be equally shared.

There will not be an intentional policy to accelerate urbanization, but the rate of future concentration of the rural population will be related to the natural rate of destruction of rural dwellings. An overall effort will be made to develop a good relationship between the spacial structure in each region with its projected productive system, social infrastructure investment (housing, education, health, recreation), and productive rural and urban investment will be used to determine the future spacial distribution of the population.

Public services in a new city or in an enlarged existing city should be planned in such a way that they allow for changes in the design and standards and in the applied technology. We believe the technology to be employed in the construction and enlargement of human settlements must be the most advanced possible, insofar as available investment resources and the proposed employment policy. The network system within each city must be considered a public service, equally available to every citizen.

It is possible that for every building a design can be reached of such a flexibility and adaptability that it will be possible to extend the building's useful life. The clue seems to lie in the functional life of certain places as related to other places within the urban space. Our impression is that in order to extend a place's functional life, it must be prepared so as to be used in many different ways.

Even if a technical revolution in house building occurres, we believe it will be a long time before low cost dwellings, adapted to the different regions' environmental conditions, can be produced industrially. Nevertheless, other plans should be considered simultaneously during the transition decades. These could be the progressive dwelling, or eventually the building of a basic core as a step toward the low cost house.

Many different publishing media have devoted their interest to experimental low cost dwellings with basic habitable conditions, combining different types of design according to family and social needs, elements prefabricated rationally either in the workshop or on the spot, or traditional systems and locally available materials. Costs and execution times, climate adaptability, alternative designs and rules, and technological variations have been the most analyzed and expounded subjects. However, in almost no country is there a generalized consensus among professionals, government officials or the general public as to a certain preference regarding a finished house as a product.

Until today, only some social sectors--those enjoying the highest incomes--have had the possibility of satisfying their needs and tastes for housing. Consequently, these sectors have been responsible for the explicit or implicit rules underlying the design and production of houses for lower income sectors. These rules usually do not comply with the lower income sectors' economic possibilities or socio-cultural reality. The progressive participation of the population's lower income sectors in community decisions regarding welfare and the satisfaction of needs will allow for the setting of realistic rules for the design and production of dwellings.

The house of the future will possibly have to have functional and space as well as hygienic qualities; have low maintenance costs, and aesthetic standards that will make the house universally accepted. Besides, these universal qualities must be adjusted to cultural and environmental aspects, which vary from region to region, and which will have some influence on the individual and collective design of the dwelling, on the materials to be used, and therefore, on the technology. A type of house that can be satisfactory in any type of conditions is neither imaginable nor desirable. A dynamic research program could show the wide range of use certain elements of a dwelling and of a constructive system could have, as well as give information on the building industry planning and organization techniques.

Technology used in building is obviously out of date. A better technology would allow for the use of certain materials that are at present not employed. There is no reason why the building industry should not develop the use of new, cheap and more efficient materials and techniques.

Discussion

Oliver Bernardini, Rapporteur

The discussion of the two previous papers consisted largely of criticism; a number of these were due to a misunderstanding of the model. These were satisfactorily dealt with by the Fundación Bariloche and are therefore not included here. This resume covers only those comments that remain as standing criticisms of the model.

Ray opened the discussion of "The Functioning of the Model and the Demographic Model" remarking that the contents had been sacrificed to the form. The demographic model violated many of the principles he was aware of. He was disturbed by the possibility of false correlations being imposed on the system by what he thought was a highly correlated matrix. As an example he cited the well known correlation of mortality rates with age classes. It would be absurd to try to explain the 20-25 mortality rate, say, by making infant mortality rate the independent variable. In his view, a population model was one of the simplest things in life. He questioned the need for a round-about way of expressing population growth, and suggested introducing specific age groups and having life expectancy uniquely determined by the age-specific mortality and fertility rates.

Ray expressed his concern that the birth rate was not influenced by the mortality rates. It was well established that fertility rates in developing countries lagged behind the dropping mortality rates by a few years. He could not understand why life expectancy should drop with an increase in agricultural production, as was implied in the Bariloche demographic model. He suggested a careful examination of the implications of the results of regression analyses before these results were finally accepted.

Mottek inquired as to what might be the real differences in prescription as advanced by the Fundación Bariloche and by Meadows and Company. The solution to the world's problems, as advocated by both parties, was in the final analysis a reduction in the growth rates of the developed countries. Whereas in *Limits to Growth* there was a concrete motivation for the developed countries (that is, avoiding pollution and the depletion of natural resources), he did not see in the proposal of the Bariloche group any motivation with similar returns for the developed countries since it was assumed that pollution was not a problem, and natural resources were considered inexhaustible over the meaningful time horizon.

Mottek could not accept the opinion of the Fundación Bariloche that there is no basic difference in approach between a normative and a projective model. It is true, he stated, that both types of models are constrained to subjective input hypotheses. However, a normative model sets goals and contains some form of optimization to reach them; a projective model does neither. Mottek inquired how the Bariloche model was to be implemented. Who optimizes? Is it a market mechanism or is there a central planning system? Who regulates?

McPherson thought the optimization too technical for the unclear problem at hand. The type of procedure applied was normal for well structured problems such as the calculation of a rocket trajectory. Control scientists have troubles even with these "relatively simple" problems. For the type of problem under discussion, the main interest is not in optimizing but in satisfying.

McPherson was not content with the assumption of just one objective when, in fact, there are multiple objectives. Where are the trade-offs? In his opinion, utility theory would provide a better approach. He suggested that weighting different utility functions such as calories/capita, urban space/person, GNP/capita, life expectancy at birth in a general objective function, would be more acceptable than maximizing life expectancy.

The meeting then turned its attention to the paper on "Urbanization and Housing". Horvath stated that he was impressed by the "learning capacity" of the Bariloche model, but observed some inconsistencies. There had been much talk about shadow prices, but what he had observed was in fact market prices. He said he understood that the annual GNP allocation for the housing investment sector was for urbanization around city nuclei. In that case, what happened in rural areas? Would the rural population be forced to agglomerate into urban centers? (This would result in an increase in costs for the agricultural sector, for example, that have not been taken into account.) Or would the rural population simply be ignored with respect to housing and services investment?

Iyengar pointed out that among the hidden assumptions of the Bariloche model was an inexorable trend to urbanization. In developing countries, people lived largely in villages. Did it seem reasonable to agglomerate the 600,000 villages of India? Is this desirable? Is it not possible to solve the problem without agglomerating, by allowing people to live where they want and by bringing services to them through improved communications? Iyengar noted that the gap between developed and developing countries was only slightly narrowed in the Bariloche model, even after the provision of development aid at the rate of two percent of the GNP of developed countries for a period of 50 to 60 years. Why did the Bariloche model not invoke substantial technology transfer? The Bariloche model assumes that technology in developing countries remains at a standstill. The developing countries are interested in narrowing the gap to zero. Can this ever happen? What is the minimum contribution in development aid needed to eliminate quickly this gap?

Non-Renewable Natural Resources and Pollution Methods

Amilcar Herrera

NATURAL RESOURCES

The mineral kingdom, which provides man with whatever he needs for his industrial production, comprises the solid portion of the earth's crust, the ocean and the atmosphere. Nevertheless, most of the mineral resources consumed by man so far have been obtained from the earth's crust. Although this superficial layer has an approximate thickness ranging from 32 to 40 km, mining operations performed up to now have seldom reached two or three thousand meters.

Even if such a thin layer is taken into account, the earth's crust contains practically inexhaustible reserves of all kinds of metals and minerals needed by man. However, most of its content is at very low concentrations and uniformly distributed throughout that layer. Under current technological conditions, they cannot be considered as available resources since the costs to mine them would be higher than their economic and social value.

What we consider exploitable under current conditions are those resources contained within geologic bodies known as mineral ores or mineral deposits. These bodies are known to contain high concentrations of certain elements or minerals. The constituent material itself is called "ore". However, "high" concentration is not enough to define whether a rock constitutes a deposit or not. It is necessary, moreover, to determine, at least approximately, which will be the value of that concentration, since there are many geological bodies containing relatively high proportions of certain minerals, if compared to the average content in the earth's crust which cannot be classified as deposits. To be thus considered, a body must contain a proportion of useful elements or minerals which could be economically recovered.

This definition seems to offer a relatively simple method of determining the level at which a mineral or metal concentration should be considered to be, in fact, a deposit. But this simplicity is superficial, since there are multiple variables which will determine whether a mining operation is economically feasible or not. Some of these variables such as shape and size, content and grade, have a geological nature and could be determined through an adequate analysis of the deposit; others such as market conditions and exploitation technology, are not dependent on the properties of the deposit, and vary considerably in time. Some variables such as distance, accessibility, climate, and water availability are likewise independent of the properties of the deposit, but often determine whether the operation is feasible or not. The exploitation of large but low grade mineral deposits will depend, to a great extent, on the means of transportation to consumption centers. In arid or desert areas, where the water for the processing plants has to be pumped or transported from distant sources, the feasibility of a mining operation will depend on whether the mineral reserves are sufficiently large to justify the considerable investment required.

Regional Reserves and Reserves Within a Deposit

The study of individual deposits is, in most cases, carried out having a more or less immediate exploitation in view. In this sense, both the uncertainty and the margin of error of the main factors to be evaluated--that is, size, shape and quality of the deposit--are too large. To bring them to an acceptable level, the mining enterprise will have to perform a series of exploratory works such as drilling, digging trenches, and tunnelling. Because of the high costs involved in these works, the firm will perform them only if the preliminary geological research warrants favorable conditions. Insofar as the economic unknowns are concerned, it is relatively easy for the mining firm to solve them, since it makes its estimates based on current economic and technologic conditions, accepting the risks involved in any commercial enterprise.

On the other hand, and more important, the mining firm will make only the necessary exploration works to make certain that it will have enough ore to continue to work for a reasonable length of time, in such a way as to be able to recover the initial investment plus an expected margin of profit. Later, the firm will carry on the exploration works in such a way as to ensure that the additional volume of ore discovered each year is at least equal to the amount mined during that period.

The situation varies when the resources of a region are estimated. First, geologic unknowns cannot be solved through explorations works, so that the calculations must then be based on geological estimates implying a considerable degree of uncertainty. The economic unknowns add a still greater uncertainty to the estimates. A definition of what is meant by ore, from the economic point of view, can no longer be based on current technological conditions since the estimation of the mineral wealth of a country or region should rest on longer term prospects. The criterion almost universally adopted for this kind of evaluation is to consider as reserve anything useful under present and future technological and economic conditions. Obviously, foreseeing those conditions means that the appraiser must take arbitrary decisions based on his own personal opinions. The result is that very often calculations of the mineral wealth of a region made by different persons give different results.

In short, it can be said that the reserves of a region or of a deposit cannot be expressed by a figure of absolute value. The estimations are only valid within certain economic conditions and with a degree of certainty that has to be specified for each case. Reserves are classified in order to satisfy this very last condition.

Classification of Reserves

The early terms used in the mining industry to evaluate deposits, and still largely used, are positive, probable, and possible reserves. Positive reserves are those already confirmed by exploration works and on whose existence and quality (yields and contents) there is enough evidence to justify the necessary investments to start production. Probably reserves have been confirmed either through mining explorations or through outcroppings, but the uncertainty concerning their quality and quantity is considerably greater than in the previous case. Possible reserves are determined through geological inference. In an operating mine, the reserves change in kind as the new explorations and developments permit a better recognition of the characteristic of the deposit.

As has been pointed out by many specialists, this classification serves well the needs of a mining enterprise since it makes it possible to calculate, with a tolerable margin or error, the minimum amount of reserves needed to begin mining operations. At the same time, it provides a means for an objective estimate of the geological unknowns.

On the other hand, to estimate the wealth of a region, the classification imposes rigid limitations regarding the different types of reserves. The geologist or economist working on a specific region must rely on geologic and economic estimations, which as previously stated offer a greater margin of error than in the case of individual deposits. Consequently, when classifying a reserve as possible, for example, the geologist or economist generally use the term in a sense unacceptable to any mining firm, since it includes minerals not exploitable under current conditions or whose existence is based on purely geological considerations. Nevertheless, because of the lack of a more suitable terminology, the same terms were used for a long time for either type of evaluation. And worse yet, at the time of publishing the data, the information needed to estimate at least approximately the accepted margin of error is not given.

To correct this situation, the U.S. Geological Survey and the United States Bureau of Mines adopted in 1944 a more flexible classification of reserves which would facilitate the evaluation of mineral resources at a national or regional level. The classification takes into account that this type of evaluation is made, in general, by people (generally economists or government technicians) who have no access to the detailed calculations made by private mining firms, and that a thorough knowledge of the various kinds of reserves in each mine is not necessary. In such studies the important thing is to estimate the overall amount of mineral resources.

The classification includes the following terms: measured, indicated, and inferred reserves that correspond broadly to the terms positive, probable and possible, respectively, of the previous classification. But, this classification allows for a wider margin of uncertainty.

The classification, although more suitable to regional evaluation, still poses two kinds of problems. The first is that generally the appraiser has no access to the information obtained by the private firms and consequently he cannot distinguish between "measured" and "indicated" reserves. Further, the class of "measured" reserves, which are approximately equivalent to "positive" reserves in the first classification, represents only the quantity of minerals required by the mining enterprises to start mining operations; consequently, its exact differentiation is not fundamental to evaluating the wealth of a region. The second problem is that the term "reserves" is always used in the sense of useful mineral under the current economic conditions. The economist, on the other hand, is equally interested in mineral reserves which could become useful under the conditions of the foreseeable future.

To solve the first problem, F. Blondel and S.G. Lasky proposed to include the categories "measured" and "indicated" in a single term "verified" that could include both types of reserve.

As regards the second problem, Blondel and Lasky recommended (in line with the criterion pointed out by Lasky in 1949) restricting the term "reserves" to the mineral considered exploitable under current conditions, including costs, price, and technology. The mineral requiring more favorable conditions than the existing ones, as well as more exploration works to uncover deposits not yet included in the categories "possible" or "inferred," is proposed to be called "potential" ore (or mineral).

In summary, to estimate a region's or a country's mineral wealth, the following equation should be used:

$$\text{Mineral resources} = \begin{matrix}\text{verified}\\ \text{reserves}\end{matrix} + \begin{matrix}\text{inferred}\\ \text{reserves}\end{matrix} + \begin{matrix}\text{potential}\\ \text{mineral}\end{matrix} .$$

In our opinion, under current circumstances, this is the formula best suited to the estimation of mineral resources at a national or regional level.

In recent years, the concept "base resource" has also been developed. According to Schurr et al. (1960) the concept "base resource" is conceived to include the sum total of mineral raw material present in the earth's crust within a given geographical area. Assuming reserves are called A, the base resource C will be equal to A + B, where B contains all of the stock not included in A, either its known or unknown existence and without considering whether it is technologically or economically exploitable. The concept "base resource" is thus absolute, in the sense that it includes all the stock within a specific geographical area.

Under present conditions, it is difficult to evaluate the usefulness of this concept. If it is applied straightforwardly, it includes all of the earth's crust whose detailed composition is mostly unknown. If any economic or technological restriction is introduced, it becomes an extension of what has been defined as potential reserve. Only by thoroughly knowing the composition of the earth's crust could this concept be of any use for guiding technological research.

What statistics show as a country's mineral resources consists of those reserves declared (verified and inferred reserves) by the mining enterprises plus the ore whose presence is deduced from the existing more general information. Almost all of this information is obtained from deposits or mining districts being either exploited or explored; consequently, most of the potential resources are calculated by the geological extrapolation of mineralized areas already known. In other words, these resources are a function of known exploitable reserves, which are, in turn, a function of the demand of the productive system.

This concept helps one to understand the meaning of figures that appear in the statistics as the mineral resources of a country or of the world. They are intended to reflect not the total mining wealth of a given area, but those resources directly or indirectly discovered by the exploration carried out up to that moment, including those resources which are exploitable under current technological and economic conditions or under conditions envisaged for the near future. This is why mining inventories are already out of date at the time they are published.

The criteria used in those inventories to include potential mineral are very heterogeneous. For example, low grade bauxites are included as potential reserves for aluminum, while non-bauxitic high aluminum content clays are excluded; the sulfur contained in gypsum and anhydrite, although economically and technologically exploitable, are not included as sulfur reserves; manganese nodules in the ocean bottom do not appear in reserve figures, although studies on the feasibility of their exploitation are being made. The reasons for these omissions are varied: sometimes the reserves are unknown but practically inexhaustible, so that it becomes a difficult task to quote them in figures. (This is true in the case of aluminum rich clays, gypsum, and anhydrite.) On other occasions, researchers estimate that the total volume of those reserves is not yet precisely known. (This is true in the case of ocean nodules.) Finally, we should keep in mind the objective with which those inventories are carried out: to give a general picture, for governments, firms, and the like, of the actual state of reserves of short- and medium-term importance. It does not make too much sense then to include reserves whose exploitation is foreseen in a distant future.

Conclusion

It is clear that the classification of something as a reserve or as a mineral resource depends on the technological and economic conditions at the time of the inventory. In other words, it is the result of making a cross section on the economic technological future. Different cross sections will reveal different pictures of those reserves for the type as well as for the volume of the material included.

This can be clearly seen if we examine recent history. During this century mankind has consumed, insofar as the most important mineral raw materials are concerned, much more reserves than those known in 1900. Such reserves, however, have not been depleted and, in the case of the most important minerals, are much larger now, in absolute figures, than at the beginning of this century.

Not only the quantity but also the quality of the reserves have changed. Only a few decades ago, the only sulfur reserves considered were those of the Frasch type, along with small surface volcanic deposits; that element is now extracted in large quantities from oil and natural gases, and gypsum and anhydrite are also included as potential reserves for sulfur. In recent decades, taconites have come to be considered iron reserves; low alumina and high silica content bauxites as well as clays have come to be considered raw materials in the production of aluminum. These are a few examples that show how the criteria involving mineral resources are evolving.

It is absolutely misleading to think of mineral resources as fixed and unchangeable stock. The concept of resources is essentially dynamic: the terms defining mineral resources--such as quantity, type, and grade--should be regarded as time dependent variables that change as economic and technological conditions evolve.

THE PROBLEM OF THE POSSIBLE EXHAUSTION OF MINERAL RESOURCES

The concern about the depletion of non-renewable natural resources plays a central role in all "catastrophist" hypothesis; all of these maintain that those resources are finite, and consequently liable to becoming exhausted.

It is obvious that the resources of the earth are limited. The real problem (disregarding for the time being what is meant by "exhaustion") is to determine how long the resources will last. If there are reasons to believe that they will last only a few decades, it then becomes necessary to begin confronting the problem immediately since, given the tremendous inertia of a system of the size and characteristics of human societies, any program intended to have global effects would have only long-term results. If, on the other hand, the resource crisis is expected within hundreds or thousands of years, it would be senseless to begin worrying today. It is impossible to predict even approximately the evolution of human societies over so long a period, and the criteria or the technological capacity with which they will confront their problems.

The Theoretical Hypotheses on Scarcity of Mineral Resources

World Model III, developed by Meadows together with a group of researchers at the Massachusetts Institute of Technology, and published under the title *The Limits to Growth* (Meadows et al., 1972) is the only research work which, using quantitative data, has attempted to answer the question of mineral resources. According to this model, if current growth trends continue, human societies will face a catastrophe by the middle of the next century. They test several alternative hypotheses, and in most of them the depletion of mineral resources is found to be directly or indirectly responsible for the catastrophe. The authors conclude that only by reducing consumption, in addition to reducing the population growth rate to zero, could the collapse predicted by the model be avoided.

Considering the influence this work has had throughout the world, and the fact that its hypotheses are always present in current literature on the subject, it is convenient to briefly analyze the validity of such hypotheses when applied to natural resources.

The two basic assumptions of World Model III on mineral resources are:

a) The total amount of mineral resources available in the earth crust is enough to meet man's needs during the next 250 years at current consumption levels. This estimate was based on world reserves published by specialized agencies, in particular, the United States Bureau of Mines. Since the life span of these reserves depends on the type of mineral raw material considered, the 250-year estimate is a reasonable average. Its application presupposes absolute capacity of substitution among the various minerals.

b) As the stock of non-renewable natural resources decreases, the cost of production for each additional unit increases, since the best and most accessible reserves have been discovered and exploited first, while more effort (capital) is required to exploit the lower "quality" and less accessible reserves. Cost is measured

> as a fraction of the world's capital that must be assigned to the exploitation of mineral resources. The cost increase is given as a function of the remaining fraction of the original stock of available mineral resources. As the remaining fraction of mineral resources tends to zero, the fraction of capital required tends to one; that is, it tends to absorb all of the available capital, hence curtailing any other economic activity. Through this simple mechanism, the progressive depletion of mineral resources leads rapidly to the collapse of the whole system.

The whole structure, and consequently the validity of this part of the model, depends on the possibility of determining the total amount of mineral resources at man's disposal.

The shortage hypotheses of the MIT model have been known for a long time in economics since they were first developed by Malthus and Ricardo. Malthus, who was specially concerned with the problem of food, assumed that there is a limited and known quantity of the resource (that is, land). He assumed that food production first increases as land development expands. At this stage (that is, while there is some unexploited land), the cost of production remains constant. Only when all of the existing land has been developed, is a point reached after which the production of each additional unit can only be obtained at a higher cost. This will lead to a situation where increasing inputs do not produce higher yields, and the highest possible production level would then have been reached.

Ricardo's hypothesis (apparently more applicable to nonrenewable resources) does not necessarily imply a resource limitation; but those resources having higher yields would be utilized first, and as they became depleted, other less suitable resources would then be exploited. The result is that costs begin to increase from the moment production starts, and will eventually reach levels so high as to make production socially unacceptable.

The MIT model combines the two shortage hypotheses. It introduces the Malthusian assumption that resources are limited, and also the Ricardian hypothesis that yields decrease from the moment production starts. It is not surprising that the combination of the most negative aspects of the two hypotheses results in a highly explosive model.

Can either of the two shortage hypotheses be applied to mineral resources?

Taking into consideration the definition of resource, it is obvious that the Malthusian assumption of a known fixed amount cannot be applied. It would only have theoretical meaning if we assume constant technological and economic conditions. In this situation, the total amount of resources would then be that which is exploitable under present conditions. A detailed exploration of the accessible part of the earth crust would make possible an exact determination of the volume and quality of those resources. What would be senseless is to use the data on reserves published periodically, as if the data were an inventory of the total amount of resources exploitable under present conditions. As we shall see later, the data represent only a fraction, probably very small, of the total amount of such resources.

The real difficulty in determining the total world mineral reserves is that the determination of whether certain geological material is considered a resource or not depends on economic and technological conditions that vary in time. Given the fact that these conditions cannot be foreseen, except in the very near future, the total amount of resources eventually available to mankind represents an intrinsically unknowable datum.

The Ricardian hypothesis, although apparently more suitable to mineral resources, is also inapplicable. Even assuming constant economic and technological conditions, the assumption that the economically more convenient resources are exploited first requires a thorough knowledge of the location and properties of all existing exploitable resources of the earth's crust.

This condition has never been met, and the reserves exploited first were not only the easiest ones to locate, but also the closest one to production centers. The European iron ores, in spite of their relatively low grade, were exploited before the high grade Lake Superior ores, simply because the Industrial Revolution started in Europe and only later expanded to the American continent.

But the Ricardian principle cannot be even intelligibly formulated when technological changes are introduced. In fact, every technological innovation modifies the criteria used to determine which resources are economically more convenient. Only a few decades ago, the nitrogen compounds used as fertilizers were obtained from natural nitrate deposits; they are now produced from nitrogen in the air. Is there any sense in claiming that there has been a change from a more convenient resource to a less convenient one from the economic point of view? The same could be said of changes in the type of resources used to produce other mineral raw materials because of the technological progress achieved since the beginning of the Industrial Revolution.

Historical Evidence on the Scarcity of Mineral Resources

It is obvious then that the theoretical hypotheses on scarcity traditionally used in economics do not apply to mineral resources. In other words, it cannot be assumed a priori that there has been any growing scarcity in the past, or that there will be any in the foreseeable future. Whether there are any signs of scarcity in the production of mineral resources, that is, whether the social cost of production has increased with time or not, can only be decided through the analysis of the available historical data.

In this respect, the prices of mineral products give the first historical evidence. Figure 1 shows that the prices of mineral raw materials have remained constant during the last one hundred years (between 1870 and 1960).

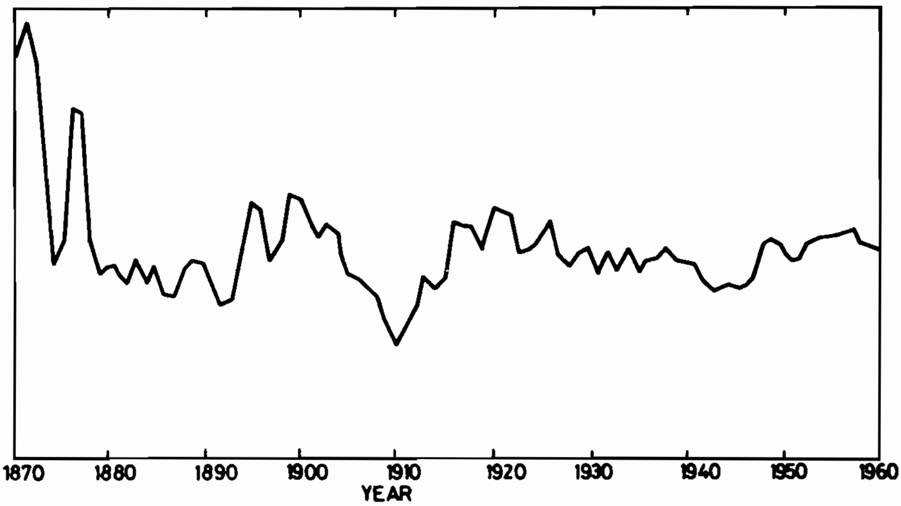

Figure 1. Evolution of the United States mineral raw material deflated prices for the period 1870-1960. (Potter and Cristy, 1968).

More important than prices are production costs. These have been compiled by Barnett and Morse (1963) in a work specifically devoted to analyzing the validity of the hypotheses on the supposed growing scarcity of natural resources. The data refer to the United States, but the conclusions have universal application since the mining industry uses practically the same technology worldwide.

Figure 2(a) (Barnett and Morse, 1963) shows the evolution of United States mining production for the period 1870-1960, and the evolution of the inputs of capital and labor. Figure 2(b) shows the evolution, for the same period, of production costs of minerals in terms of inputs of capital and labor in the United States.

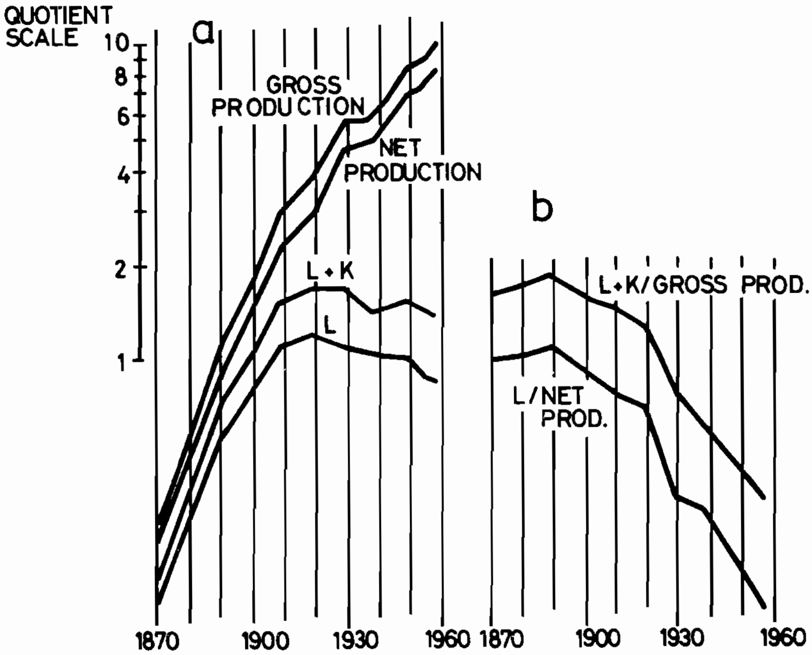

Figure 2a. Evolution of the mineral production in the United States between 1870-1960, and evolution of inputs of capital and labor.

Figure 2b. Evolution of the cost of production of minerals in terms of inputs of capital and labor, for the United States between 1870-1960.

Source: Barnett and Morse, 1963.

After analyzing these data, Barnett and Morse concluded that the factual result is, again, exactly the opposite of hypothetical predictions, except during 1870-89 (when, coincidentally, the data are rather weak). From 1890 onward, costs per unit of net mineral output, measured in either labor and capital, have declined rapidly and persistently. By the end of the period, the cost of labor and capital per unit of production was only one-fifth as large as in 1889. The decline is even greater for labor cost alone. Again, the increases in productivity were more rapid in the latter half of the period than in the early half. From 1889 to 1919, it is estimated that the labor and capital cost of minerals declined at the rate of 1.2 percent per year; from 1919 to 1957, the rate of decline was 3.2 percent per year.

It is important to add that the highest rate of cost decline coincides with the period of the highest increase in mineral demand recorded in history.

In conclusion, the analysis of the available historical information indicates that there are no recorded signs of growing scarcity of mineral raw material, and that these products were obtained, up to now, at a continuously decreasing social cost.

THE AVAILABILITY OF MINERAL RESOURCES IN THE FORESEEABLE FUTURE

Is there any possibility of those signs of scarcity which did not appear in the past appearing in the future? To answer this question, it would be necessary to determine, at least approximately, the total amount of the earth's obtainable mineral resources.

Considering that the definition of resources makes sense only in terms of a given technology and economic system, it is clearly impossible to determine the total amount of non-renewable world resources because this would require the fulfillment of two conditions: a) a detailed knowledge of the physical and chemical properties of the portion of the earth's crust eventually accessible to man; and b) an accurate forecasting of the scientific and technological advances to be achieved in the foreseeable future. Both conditions are obviously out of reach of our present scientific capability.

The real problem, however, is not to know the total amount of resources eventually available to mankind in an unlimited time horizon, but to have a general idea of the potential reserves of mineral resources exploitable under the technological and economic conditions prevailing today, or under those that can be safely predicted for the near future. This will allow a calculation to be made of whether the time available for developing technologies to use new geological materials is sufficient to avoid future production bottlenecks.

The Mineral Resources of the Earth's Crust

Many estimations have been made concerning oil reserves. Weeks (1958), Poque (1946), and Levorsen (1950) were among the first to calculate the world oil reserves. More recently, Hubert (1962) and Zapp (1962) have calculated total reserves for the United States.

The estimation of mineral reserves entails a different problem from the one involved in calculating oil reserves. Oil is a unique product, whose definition does not change with time, and whose geological location is well-known. The definition of resource for other mineral products, especially metals, changes with time. Moreover, even in a given resource, the geological characteristics of the deposits are, in general, much less known than in the case of oil.

A calculation of this kind, therefore, can give only a rough idea as to the amount of resources contained in a given portion of the earth's crust. However, for the purpose of this work, this is sufficient.

For our calculations we included only the most important metals since they are considered, together with fossil fuels, the most critical from the point of view of their possible depletion. For a first estimation of the probable amount of reserves of exploitable resources under present conditions, we started from the following premises:

a) Metals are extracted from mineral deposits whose average depth, considering the whole world, is approximately 300 meters. In some cases the maximum depths reached exceed 3,000 meters.

b) The total amount of known reserves (the exploited, plus the remaining ones) constitutes one half of the reserves contained in the emergent part of the continental crust up to a depth of 300 meters.

c) The density of deposits encountered on the surface, or very close to it, remains more or less constant up to a depth of about 3,000 meters.

The calculations show that the total estimated resources of the upper 3,000 meters of the earth's crust are at least 20 times greater than the total known and exploited reserves.

Paramarginal and Submarginal Resources

Even if no new deposits are discovered, mineral reserves can increase. Historically, this has been the rule and not the exception. "Paramarginal resources" as defined by McKelvey (1971) are those reserves which could be exploited under present technological conditions at a cost 1.5 times higher than the cost of the deposits being currently exploited. This cost gap could be easily bridged by technology (as it has been proved many times in recent decades), and it would allow an increase in reserves by the incorporation of low grade ores which have not yet been computed as reserves.

Other resources classified as submarginal by McKelvey are those which could be exploited, under present technological conditions, at a cost two or three times higher than current costs. The speed at which technology advances permit a prediction that within 30 or 50 years those resources will surely be used.

The incorporation of present paramarginal and submarginal resources would multiply the known reserves of most minerals.

Copper offers a good example of the expansion of reserves by the incorporation of low grade ore. Studying the known history of copper deposits, S.G. Lasky (1950) discovered that there is a general relationship between the volume of reserves and their average copper content. This relationship (often quoted in the well known President's Material Policy Commission Report, 1952) postulates that the volume of reserves increases as the average copper content decreases. Taking this relationship into account, Landsberg et al. (1963) presume that the total copper reserves outside the United States, excluding the socialist countries, are estimated at around 200 million tons contained in ores with copper grades ranging from 6 percent in the Congo region to 1 to 2 percent in Chile; reserves could reach 400 or 500 million tons if deposits with up to 1 percent copper content were exploited, and up to 800 or one billion tons if ore deposits with 0.5 percent copper content were included. At present it is possible to exploit deposits with 0.4 percent grade at essentially the same costs as those with 1 or 2 percent content.

The same exponential increase of the reserves as the grade decreases has been determined for manganese, aluminum, titanium, nickel, zinc and columbium. This suggests that the relationship is not exceptional but most probably a general law determining the distribution of elements in natures (Brooks, 1973).

The last 30 years have seen bauxite reserves increase considerably because of technological developments that allowed the use of "lower" quality deposits. In 1930, bauxite of economic grade had to have 60 percent alumina content, and no more than an 8 percent of silica. Twenty years later the accepted alumina content was lowered to 50 percent, and that of silica raised to 15 percent.

Up to the 1950s the main source of sulfur was the Frasch type underground deposits. The price boom registered at the beginning of that decade stimulated the search for alternative sources of sulfur. The main "non-conventional" resources were oil and high-sulfur natural gas which now satisfy a significant share of the demand for that element, in spite of the fact that Frasch type reserves have increased considerably during the last two decades. Other alternative sources being used in some countries are pyrite, gypsum and anhidrite, whose reserves are practically inexhaustible. Finally, if the future pollution control measures require a recovery of the sulfur given off as industrial fumes, the production from this source will be so high that primary production would probably have to come to an end (Fischman and Landsberg, 1972).

The following are further examples of decreasing exploitable grades (Guillemin, 1972):

Lead: from 2.1 percent in 1925 to 0.6 percent in 1971;

Zinc: from 2.75 percent in 1925 to 0.6 percent in 1971;

Tin: from 1.2 percent in 1925 to 0.015 percent in 1971.

As Figure 3 shows, in spite of the changes in type and grade of the exploited materials, the price of the elements mentioned above has remained practically constant for the last 100 years.

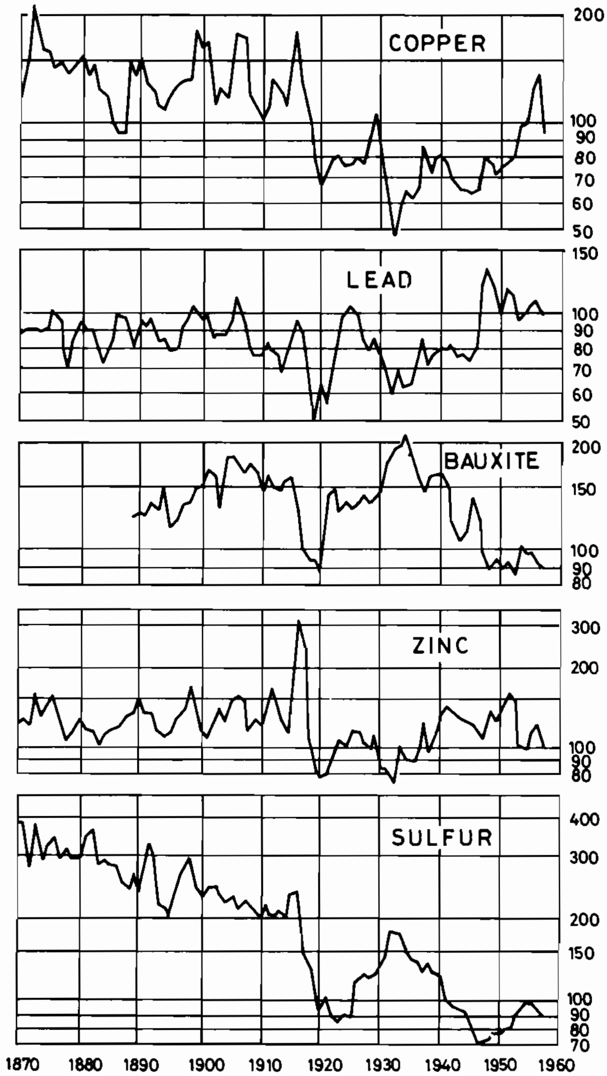

Figure 3. Evolution of deflated prices of copper, lead, bauxite, zinc and sulfur in the United States for the period 1870-1960 (Potter and Cristy, 1968).

The examples given suffice to show that, independent of the discovery of new deposits, the available mineral resources increase constantly as technology advances, even if the technology does not experience very significant break-throughs.

THE RESOURCES OF THE OCEAN BOTTOMS

In recent years, ocean bottom studies have revealed the existence of large deposits of manganese nodules and crusts with significant amounts of some of the most important metals used in industrial production. Samples have been taken from only a small portion of the total ocean surface, but the frequency with which the samples show the existence of manganese indicates that such deposits undoubtedly cover most of the ocean bottoms.

The density of those deposits varies according to the different zones. The average concentration in the East Pacific, according to the available information, amounts to 0.78 gr/cm^2, while in the middle of the Pacific Ocean the figure is 1.45 gr/cm^2 (Mero, 1960).

The metal content also varies. According to Mero, the average content would amount to approximately the following:

	Average % in the Pacific Ocean	Average % in the Atlantic Ocean
Manganese	24.20	16.30
Cobalt	0.35	0.31
Nickel	0.99	0.42
Copper	0.53	0.20

Assuming a 1 gr/cm^2 average density, only the Pacific Ocean's total reserves would amount to 1.8×10^{12} tons of nodular material, with approximately 4×10^{11} tons of manganese, 10^{10} tons of copper, 2×10^{10} tons of nickel and 1.3×10^{10} tons of cobalt. These reserves are sufficient to meet world demand, at current consumption rates, for several thousand years. Although these calculations are only approximate, they are sufficient to show the importance of these resources.

It would also be interesting to see what possibilities there are, under current technological conditions, of starting exploitation of these reserves. Several firms interested in the exploitation of such resources have already requested the exploration permits and have also calculated production costs.

The possibilities of economic exploitation of these ocean nodules are very hard to calculate on the basis of present data. Sorensen and Mead (1968), relying on the average content of nodules given by Mero, and assuming that the operation is being carried out in the Pacific Ocean at about 6,500 km from the processing plant (near Los Angeles), have concluded that, under present conditions, the exploitation would be at an economic loss. Another estimate made by the Bureau of Mines Marine Mineral Technology Center (Christy, 1970), using data different from those used by Sorensen and Mead, concludes that only if the operating firm does not have to face development costs will the exploitation of those resources be profitable.

The estimates mentioned above were obtained on the basis of current prices of the metals considered. A further difficulty comes into play because this kind of exploitation requires processing of large volumes of ore. This, in turn, may be expected to have a negative effect on the prices of the extracted metals. These variations in prices have been calculated by several authors who have also reached differing conclusions. According to Brooks (Christy, 1970) prices would decrease as follows: manganese 45 percent; nickel 7 percent; cobalt 33 percent. Sorensen and Mead calculated that the reduction would be 3.13 percent for manganese, 3.67 percent for nickel and 27.43 percent for cobalt.

The time and way in which ocean bottom metal resources are to be exploited will depend on the reduction of extraction and treatment costs. This can be achieved without major improvements in the known technologies. Referring to this problem, Christy (1970) states that most of the cost estimates mentioned above refer to the first entrepreneurs to enter production. But as Sorensen and Mead point out, second generation dredges, designed on the basis of experience gained by the pioneering firm, could give much higher returns. It would be convenient, therefore, to wait to be the second or the third firm in the business. It should be pointed out, however, that profits resulting from the second or third effort to reduce cost could become self-defeating by price reductions resulting from a surplus production released to the market.

According to Sorensen and Mead, other elements can tend to worsen this effect. With high capital investments and low operation costs, producers are tempted to produce as much as possible in the shortest time so as to recover their investments. Production could also be artificially stimulated by yield requirements imposed through international authorities to curtail speculation arising from holding the exploitation rights. Other factors leading to the same results could include competition for prestige among nations, and the corporations' desire to gain experience as well as competitive advantages over other corporations. As pointed out by Brooks, although it is not difficult to create institutions to limit the race for rights of exploitation of the ocean bottoms, this does not help much to control overcapitalization and overproduction due to the nature of the resources. However, eventually the market will reach an equilibrium; new uses will be found for the extracted metals and new firms will be able to participate without significantly diminishing their profits.

Although it will probably take a long time before the mineral resources of the ocean bottom are exploited, this will depend on technical and economic problems whose solutions do not depend on future revolutionary changes. Consequently, they are resources which increase the reserves of some of the most important industrial metals in several thousand years at current consumption rates.

LONG-TERM PROSPECTS

The short analysis given above shows that the available mineral reserves which can be extracted under current or near future technological conditions are most likely sufficient for several thousand years at current consumption rates. In view of this conclusion, it does not seem necessary to try to determine the additional resources contained in our planet. However, given the confusion existing with respect to the ultimate reserves of the non-renewable resources of the earth, we shall add some observations.

First, in order to estimate probable reserves of conventional resources still remaining, we have only considered the first 3,000 meters of the earth's crust, as well as the surface of the ocean bottoms. As has been pointed out, there is no reason to suppose that mineral deposits do not go to much greater depths, even though the overall composition of the resources will vary. Some types of deposits will surely be less frequent at greater depths while others will be more abundant, but there is little doubt that the reserves of most of the industrial minerals could be increased several times. Other deposits could be added, especially those lying within the continental shelves, or even below the sedimentary layers of the ocean bottoms. The conventional resources--that is, those exploitable under current or near future economic conditions--are only an unknown but undoubtedly small fraction if considered in absolute terms of the total resources eventually available to mankind.

Historical evidence proves that it is very difficult to predict which sources will be used in the distant future as suppliers of mineral raw material; we shall therefore illustrate this point with a few examples.

Iron is one of the most abundant elements in the earth's crust. Available data suggest that conventional deposits will continue to be the main source of iron for a long time. There are other sources of iron, however, with huge potential reserves; the basic and ultrabasic rocks of the earth's crust with approximate iron contents of 8.5 and 9.8 percent, respectively. This means that a cubic kilometer of basic rocks contains approximately

2.6×10^8 tons of iron, and one cubic kilometer of ultrabasic rocks will contain more than 2.2×10^8 tons. To obtain an idea of the importance of these figures, it is sufficient to point out that this type of rock covers approximately five percent of the earth's crust. As to the possibility of exploiting this type of resource, Flawn (1966) states that the large set of silicate igneous rocks contains significant mineral quantities, some of them in high concentrations. The use of these rocks is not yet practical either from the economical or the technological point of view. Nevertheless, these reserves will be used selectively in the future. The selection will be based on intensive explorations and analyses to determine the maximum concentration of this or that group of elements. The key to success consists of developing rock grinding techniques, better systems of mineral separation, and in the economic recovery of several elements rather than just one.

On this topic, Brooks (1973) maintains that it is false that common rocks will never be exploited. In fact, we are already exploiting, as by-products, minerals whose average content is lower in the deposit than in the earth's crust (titanium extracted from sand, for example). Utilizing technology as capital, rather than the deposits themselves, the very fact that they are common rocks can turn them very attractive. The more common the rock the easier it becomes to adjust the deposit to the technology instead of the opposite. In short, through modest technological development, mineral deposits become more abundant and more frequent.

Considering the constant decrease in the exploitation grades, Guillemin (1972) states that at the limit, and for pessimists, it should be remembered that a large proportion of the earth's rocks contains vein metals (Pb,Zn,Cu,etc.) with amounts varying from 100 to 300 grams of metal per ton. Accordingly, 100gr/ton of a metal in a km^3 of granite, represents 270,000 tons of that element. Later, he adds that there are plenty of potential ores, as the bituminous schists which contain important reserves of several elements; granites rich in vein elements; basic rocks with a high content in nickel, chrome, cobalt and platinum; carbonate rocks rich in lead and zinc; certain underwater sediments, and finally, brines rich in metals of the type discovered in the Red Sea, which can be considered as liquid ores.

Aluminum offers a particularly interesting case. We have already seen how, in recent decades, the reserves of bauxite have increased greatly because of the incorporation of low quality material. The most important thing to point out, however, is that some non-bauxitic materials have already been used as sources of aluminum (Brübarier, 1966). High alumina clays, anorthosites and nepheline are some of the non-bauxitic ores. Considering that clays are among the most abundant minerals of the earth's crust, aluminum reserves increase almost indefinitely.

There are other such examples of potential resources. Some of them have already started to be put into use, as for example the recovering of sulfur from oil, anhydrite and gypsum; and the discovery of commercial concentrations of beryllium obtained so far from pegmatites in bertrandite and phenacite. What is most important, however, is that the careful analysis of the distribution of elements in the earth's crust has only recently started which makes highly probably the continuous discovery of new mineral deposits.

What will be the sequence in which these new resources will become incorporated into the economy? Some current hypotheses seem to assume that new resources are incorporated by the productive system only when the "original" source becomes or is about to become depleted. These assumptions raise the fear consistently present in current literature that even though the ultimate amount of possible resources may be practically unlimited, an eventual time gap between the depletion of one type of reserve and the time needed to develop and put into use a new one could create bottlenecks in the supply of raw material which, while temporary, would be nonetheless disastrous to the economy as a whole.

History shows that this phenomenon is not likely to happen. In fact, it would be difficult to find a case in which a new resource has been used because of the depletion of a previous one. What usually happens is that new types of resources are put into use long before the ones presently used become depleted. Nitrogen compounds used in the production of fertilizers were synthesized by fixing nitrogen from the air at a time when there were still enormous reserves of natural nitrates; in the United States, taconite, an ore which requires a special treatment, is being used as an iron ore even though there are sufficient high grade mineral reserves worldwide to supply the industry for many decades; aluminum is being produced from non-bauxitic minerals, while high bauxite deposits are constantly increasing the already large reserves of such material; technologies have been developed to exploit deposits with 0.4 percent copper content, while there are still huge reserves with higher copper content; the exploitation of the manganese nodules of the ocean bottom is being considered, even though there is no danger of exhaustion of the metals to be recovered.

All these facts tend to indicate that the same phenomenon will occur in the future. There is no reason to assume that deposits located at greater depths will be used after surface resources become depleted. (In fact, mineral deposits at great depths are already being exploited.) What is most likely to happen is that low grade mineral deposits will continue to enlarge known reserves, while explorations are carried out in the less known portions of the earth's crust, beginning in those areas which offer greater possibilities. Ocean bottom deposits will start to be exploited in accordance with market conditions and, simultaneously, with continental deposits. The exact sequence of these developments will depend on social, economic and technological conditions that are very difficult to foresee in detail.

Critical Resources

It has been frequently stated that although critical shortages of the most important mineral resources are not likely to appear, it is possible that some quantitatively minor elements (but important to modern industry) may become scarce or totally depleted. Since this hypothesis cannot be completely disregarded, we shall briefly discuss it below.

The most important uses of mineral raw materials can be divided as follows: structural, electrical, ferro-alloys and chemical.

Non-metalic structural materials are practically inexhaustible. The main structural metals are iron and aluminum, which appear among the earth's crust as the most abundant elements (Al: 8.13 percent; Fe: 5 percent). Under present technological conditions, aluminum resources are practically unlimited. Current iron ore reserves seem to be sufficient for the foreseeable future; if we consider the reserves contained in iron rich rocks, the situation resembles that of aluminum.

Concerning electrical uses, mainly as electrical conductors, the most important elements are copper and aluminum. Even assuming that in a distant future copper became scarce, aluminum, essentially inexhaustible, could replace copper in almost every use, and especially in those which require a larger volume of the metal.

Some of the elements used in ferro-alloys--such as tungsten and molibdenum--are said to have relatively scarce known reserves. Even assuming that future discoveries will not suffice to meet growing world demand (which is unlikely to happen), it should be kept in mind that these elements are easily replaceable in most uses by other metals, such as chrome, nickel and cobalt. World known reserves of chrome are quite large; nickel and cobalt reserves contained in the ocean bottoms are potentially sufficient to meet world demand for many thousands of years, even without considering the resources under exploitation today.

The two most important industrial chemical elements are phosphorus and sulfur. Sulfur is important in industrial production, while the main use of phosphorus is in the production of fertilizers.

We have already discussed sulfur. The possibility of having to face a phosphorus shortage has been one of the main concerns of recent literature. The real situation, however, does not seem to justify such preoccupation. Current phosphorite reserves under exploitation seem sufficient to meet future demands (Landsberg et al., 1963). On the other hand, since sedimentary deposits of phosphorus are difficult to discover without detailed exploration, known reserves of this element would probably be multiplied if better exploration techniques were used. The same is true in the case of bauxite. This mineral is not easy to detect unless special techniques aimed at specifically identifying it are used.

There are large phosphorite deposits in the ocean bottoms close to continental shelves which could be successfully exploited under current conditions, thereby extending available reserves to meet future demands. Further, phosphorus is one of the minor components of many rocks and ores which, if necessary, could be treated to recover the element as a by-product.

There are many other elements used by the chemical industry; however, they are so varied and chemical technology develops so rapidly that substitution possibilities are practically unlimited.

In short, there is no evidence that, even in the distant future, there will be a danger of shortage of mineral resources necessary for the current productive system. The eventual scarcity of some minor element may induce some technological changes, probably without noticeable effects on the productive system as a whole.

The Concept of Exhaustion of Mineral Resources

It is important, at this point, to reconsider the common view that since the earth is finite, its resources are also finite. This is obviously true, but the fallacy lies in equating exhaustive and finite, when in fact these terms express completely different concepts. Except for a few cases, the vast volume of the earth's mineral resources, although used, continue to be part of the earth's resources as if they had never been extracted. They can be disseminated throughout the earth or spread over the oceans; they can be chemically combined with other elements; they cannot be destroyed. Technology which has shown its ability to extract resources from the most varied geologic bodies, can also help to recover materials which have been used by man a number of times.

The Long-Term Evolution of the Prices of Energy

Carlos E. Suárez

INTRODUCTION

The present work has been prepared with the aim of establishing the probable long-term evolution of energy prices. This subject is of great importance since the Model assumes that energy constitutes a basic generalized input which, besides playing a current role in the world's economic activity will have to contribute to the control of some variables of the Model; these include pollution, the eventual production of synthetic foods, the extraction of low-concentration minerals and the re-cycling of raw materials.

Current knowledge of the total resources of primary sources of energy (for oil, see for example [2]), as well as the predictable evolution of technological development for exploiting new sources of energy (fussion, hydrogen, solar energy, geothermal energy) do not establish physical limits to the availability of energy on a world-wide scale. Thus it must be determined whether this availability will not require significant increases in the real price of energy, so that the above mentioned resources may effectively reach the consumer.

OUTLINE OF ANALYSIS AND METHODOLOGY

Outline of Analysis

The evolution of the prices at site of production of the three primary sources of energy--coal, oil and natural gas--will be discussed.

Subsequently, the evolution of the prices of electrical energy, as the main form of secondary energy, is analyzed. In this connection, the average sale price to the final consumers will be considered, in order to take into account the whole process of transforming fuels and to be able to simultaneously consider electrical energy of thermal and hydraulic origin.

Finally, a brief analysis is made of the recent development of energy prices within the framework of their long-term evolution, and of the repercussions of this development on conditions of different groups of countries.

THE PRICE OF COAL AT MINE

The evolution of the price of coal at mine will be analyzed because from the beginning of the last century until World War II, coal has been the main primary source of commercial energy on the world market. In addition, coal as a primary source of energy constitutes the greatest proportion of known reserves; the resurgence of its use is envisaged through the processing of coal into liquid and/or gaseous fuels.

Figure 1 shows how the price of coal has evolved from 1870 until 1972 according to the data on average prices f.o.b. at mine of a ton of bituminous coal produced in the U.S. The data show that the prices of coal maintained a great stability and constancy during the 50-year period of 1870 and 1919, with short-term oscillations in the order of 15 percent of the average value.

Figure 1. Evolution of the average price of the bituminous coal in mine/period (1870-1972 in United States). (Index relative to the general price index 1947-1949 = 100).

Between 1920 and 1924, the real price of coal changed suddenly, with an increase of 70 percent over the previously mentioned average value; however by 1925, it returned to the normal level. This anomaly was probably caused by a monetary maladjustment between the price index of coal and the general price index which in 1921, decreased suddenly by 37 percent following the inflationary process that paralleled World War I.

Only from 1930 onwards was there the beginning of a clear trend toward an increase in prices measured in constant currency. This increase extends until 1949, with small short-term oscillations around this general trend, and reached a level 75 percent higher than the average price level of the period 1870-1919.

Between 1949 and 1968 this tendency reverses itself significantly until it reaches levels similar to those of 1934-1937, which are only 30 percent higher than in 1870-1919. The period 1870-1919 is characterized by an intense process of mechanization and automation in the exploitation of coal, and also by a change in the characteristics of the type of mines exploited, favoring those of greater productivity (for example auger and stripping mines [7]).

Finally, between 1969 and 1972 there is an increase of real prices of about 50 percent, which exceeds the maximum levels reached in 1922 and 1949 by some 12 to 13 percent. This sudden increase of prices is more intense than the one recorded for the period 1942-1949, but it is smaller than the increase of the period 1919-1922. In both cases, the trends changed rapidly again, returning to levels similar to those existing prior to the crises.

What causes produced the latest trend, and what is the probable future evolution? The causes of this crisis have nothing to do with problems related to the exhaustion of reserves; the causes are short-term market factors (delay in the planning of nuclear power stations, international problems in relation with oil, the activity rate of the world iron and steel industry, and more recently, the price increases in the international oil market), as well as long-term factors (such as pollution and working conditions in the mines [4]). The first type of problems will no longer have any influence once the short-term market situation is overcome, but this is not the case with the long-term problems.

It seems clear that the answers should be sought in technological development, since this allows at least a partial recovery from the recent increase in prices. And, parallel to this, the prospect of a substantial increase in production levels may benefit costs through economies of scale.

It is difficult to predict significant reductions of real prices after the crisis [4], which would leave, as a long-term balance, a growth tendency in real prices of coal at mine, with an annual rate of about 1.3 percent.

Paradoxically, this tendency can be observed in the case of fuel which shows the least problems of exhaustion of reserves, and at the same time the greatest participation of labor costs in total costs.

THE PRICE OF OIL AT WELL HEAD

Evolution in the United States

At present, an intense international discussion revolves around the price of oil, for the "ghosts" of exhausted known reserves and price growths have reappeared as they have done in the past.

Fortunately, the detailed and objective analysis of historical data and the careful consideration of works such as The World Petroleum Market by M.A. Adelman, allow us to affirm at the end of this report that the real price of oil, although with large temporary variations, has evolved over one hundred years of life of the industry at a basically constant level. Therefore, the current price situation may be considered only one more of the already indicated variations; at present it is above the average values, but in the future there will be a return to the average level, at least until oil is replaced by other sources of energy in its function of determining energy prices.

A similar statement is made by John Fisher in Energy Crisis in Perspective, where he says that the real price of oil in the United States has decreased 5 percent with each doubling of the cumulative production, and that it will continue to be stable at least for two doubling periods of about 50 years.

In Figure 2 one may observe the evolution of the average well-head prices expressed in dollars/barrel for the period 1870-1974 in the United States. The data show that the real prices of

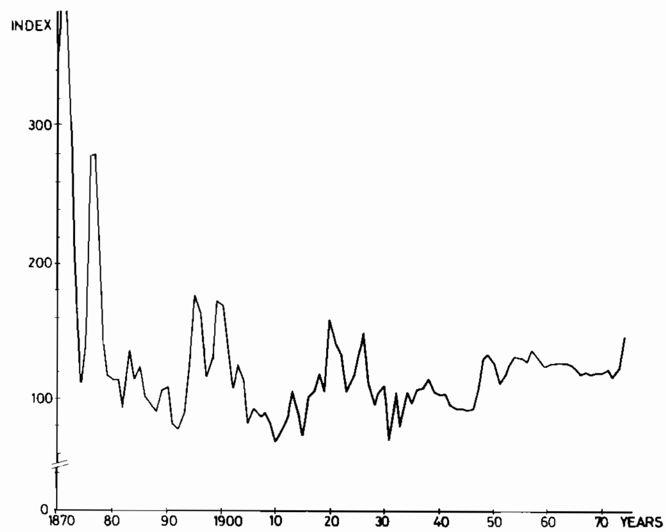

Figure 2. Evolution of the average price of oil at well head in United States (1870-1972 period).

oil have undergone variations in the short-term, much greater than those of coal, under the influence of problems of a conjunctural type (world wars, local conflicts, economical and political crises); however clear stability and constancy in the long term of this real price are noted, and there is even a sort of mitigation in the conjunctural oscillations around the mean value which for the period 1870-1974 is 125.4 percent.

After a rapid fall in prices during the first decades of the existence of the oil industry, a series of oscillations are observed around this mean value which for the period 1880-1920 are of the order of ± 50 percent and for the period 1920-1950 of ± 30 percent; between 1950 and 1974, it does not surpass ± 15 percent.

It is important to emphasize here how the real average price, expressed in terms of constant currency, has declined by 14 percent during the period 1957 and 1972. There is a small increase in 1973, but the index continues to maintain a stable level similar to the one for the period 1965-1972. The rupture is produced with the estimated figures for 1974, above all if the price of oil not subjected to governmental regulation is taken into account; in this case the increase between 1972 and 1974 would be 61 percent rather than 24 percent if the value (a) is taken. This is not the first time that this type of price rise is recorded in the history of the oil industry in the United States: between 1874-1877 it was 152 percent; 1893-1895, 99 percent; 1915-1920, 116 percent and between 1945 and 1949, 45 percent. However, none of these increases implied a modification in the long-term tendency which is constant. Therefore from the historical process there are not sufficient arguments to ensure that the present increment will be permanent.

This brief analysis of the present situation in the United States reveals that the statement about the constancy of oil prices over the long term cannot be disputed for the United States, not even when more recent data are used which correspond to an unstable situation and a temporary crisis.

In the country where the oil resources of the region have been used most intensively, where the current energy "crisis" is centered, and where the prices reflect the real cost of production to the greatest degree, one does not find in the long term a pressure to increase the price of oil expressed in terms of constant value currency.

The Evolution in the International Oil Market

It may be asked if this assertion, valid for the United States, is also valid for the international oil market where the stipulated and/or effective prices, measured in standard currency, have had substantial increases during recent years. To be able to interpret the evolution of the international oil market, we will carry out two types of analysis. One type is quantitative, linked to our criterion of approaching the problem always on the basis of costs or prices expressed in terms of "constant currency." The second type is of a qualitative and conceptual nature that attempts to identify both the real reasons for the process and those who gain or lose as a result of the process.

Evolution of the International Prices of Oil Deflated with the General Wholesale Price Index in the United States

In Table 1, the evolution of the posted prices of two typical crude oils may be observed, one from Venezuela and the other from the Middle East, both deflated by the General Price Index of the United States. In both cases the policy of the multinational companies that desired to enlarge their markets--especially those of Europe and Japan--consisted in reducing step by step, starting in 1960, the posted prices of the crudes expressed in standard dollars. This is a procedure which implied a substantial reduction if the deflated values are considered (-26 percent between 1957 and 1971 in the case of Venezuela). This reduction is even greater, if instead of considering the posted prices, the effective prices are taken into account. In the case of Venezuela, the reduction between 1957 and 1970 reaches 44 percent if the average effective prices are deflated using the general index of wholesale prices in the United States.[1] In both cases, the decrease is greater than the one recorded during the same period of the average price in the United States, since the latter reached only 13 percent.

As a result of this situation, (which is unsustainable for the exporting countries), the reaction of 1971-1972 occurs, thereby bringing the posted prices, and also the effective prices, to the levels of the mid-1950's.

This statement is also valid for the average value of 1973 corresponding to Venezuela, but it is not valid for the value corresponding to Iran. It is also clearly unsustainable for the value corresponding to the first quarter of 1974, since these are 2.7 to 4.5 times greater than the highest levels reached during the 1950's.

How are these values to be explained in relation to our statements about the constancy of the long-term prices expressed in terms of constant currency?

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[1] See [1, Tables V-A-4 and 10].

Table 1. Evolution of the posted prices of oil.
(deflation with the price index of the United States)

Date		VENEZUELA 31 -32oAPI		IRAN 31 -31oAPI	
	Standard price d/b	Constant price d/b 1947	Index 1951-110	Constant price d/b 1947	Index 1951-110
1951	2.28	1.92	110.0	1.47	110.0
1952	2.28	1.97	112.6	1.47	112.3
1953	2.28	2.00	114.2	1.47	114.2
1954	2.53	2.21	126.2	1.67	129.1
1955	2.55	2.22	126.9	1.67	129.1
1956	2.55	2.15	122.9	1.67	124.9
1957	2.80	2.30	131.4	1.67	121.2
1958	2.80	2.26	129.1	1.80	129.1
1959	2.80	2.22	126.9	1.80	126.6
1960	2.55	2.06	117.8	1.62	116.6
1961	2.55	2.06	117.8	1.63	116.9
1962	2.55	2.06	117.8	1.63	116.9
1963	2.52	2.04	116.5	1.63	116.9
1964	2.52	2.04	116.5	1.63	116.9
1965	2.52	2.00	114.2	1.63	114.1
1966	2.52	1.93	110.4	1.63	110.6
1967	2.52	1.93	110.4	1.63	110.6
1968	2.52	1.88	107.4	1.63	108.0
1969	2.52	1.81	103.5	1.63	108.5
1970	2.52	1.73	98.9	1.63	199.0
1971	2.52	1.69	96.09	1.72	101.8
1972	3.08	1.99	113.8	2.48	139.9
1973	4.27[a]	2.56	133.2	3.30[a]	175.6
1974	11.00	6.05	346.5	11.65	567.5

[a]Average.

Sources: [3]

1973-74. Petroleum Press Service, several issues.

Evolution of the International Prices of Oil, Deflated in Relation to the Price of Gold

Table 2 shows the values corresponding to the two typical crudes which were being analyzed at the international level. It can be seen that the evolutions of the indexes are equivalent to the ones that result from using as a deflator the general index of wholesale prices in the United States until the year 1972; but from that time on, a clear difference between the two indexes becomes apparent.

Table 2. Evolution of the posted prices of oil. (deflation with gold index)

Date	VENEZUELA 31 - 32oAPI Standard price d/b	Average Index (1957-59 = 100)	Index relative to gold (Av. 1957-59 = 129)	IRAN 31 - 32o API Standard price d/b	Average Index (1957-59 = 100)	Index relative to gold (Av. 1957-59 = 129)
Av. 1957-59	2.80	100	129	1.75	100	126
1967	2.52	90	116	1.63	93	117
1969	2.52	90	89	1.63	93	90
1970	2.52	90	100	1.63	93	100
Feb. 1971	2.52	90	105	2.13	122	138
1972	3.05	109	107	2.23	127	122
Jan. 1973	3.25	116	81	2.53	145	98
Mar. 1973	3.60	129	69	2.53	145	76
Aug. 1973	4.05	145	62	2.99	171	71
Sept. 1973	4.40	157	69	2.99	171	72
Oct. 1973	4.55	162	73	3.97[a]	227	99
Nov. 1973	6.95	248	118	5.05	288	133
Dec. 1973	7.15	256	109	5.00	286	118
Jan. 1974	11.10	396	144	11.64	665	234
Apr. 1974	11.10	396	102	11.64	665	168

[a]Average.

Source: Oil Prices: Petroleum Press Service, several issues.

In 1971 and 1972 the gold deflated index rises like the previous one, but in a different way; it turns out to be higher in the first year (decline in the price of gold) and lower in the second one (recovery of the price of gold).

However, during the year 1973, a completely different behavior can be noted. Thus we can see that compared to the rapid valorization of gold, the increases effected in the posted prices remain far behind and the index decreases in July 1973 from approximately 100 in 1970 to 36 and 48, for Venezuela and Iran respectively. That is, compared to the price of gold, the prices of oil had been reduced to 50 percent of its value during the period 1970-1973.

The strong increases of oil prices in October and November 1973, which coincide with a slight decrease of the quotations of gold, determine a rapid recovery of the index, which reaches values similar to the ones in 1967, when both oil and gold had stable quotations.

Only the increases decided for the first quarter of 1974 imply substantially higher values, especially in the case of the Middle East crudes. But if the values confirmed for the second quarter are taken (despite the strong pressure from Saudi Arabia and Egypt to reduce them), it will be noted that the new rise in the quotation of gold determines, in the case of Venezuela, the similarity of the index to the one of 1970-1971, while in the case of the Middle East it surpasses by only 33 percent the value of the average of 1957-1959.

These results leave open the question proposed previously concerning the internal prices of the United States, as regards the level of international prices. Therefore, to what extent can we speak of increases of oil prices in terms of constant currency, if this increase disappears in modifying the deflating index?

Qualitative Analysis of the Evolution of the International Oil Market

It seems pertinent to quote Massé [6].

After pointing out that one cannot speak of a fair price of oil, either determined by an arbiter or by the market (both non-existent), Massé refers to the "Games Theory" as an adequate instrument for evaluating the existence of a price of equilibrium and in this sense says:"...Another form of game dominates the previous one (a random factor in the search of oil). It is the complex game which develops among the producer States, the consumer States and the oil companies...In a situation of this kind, there is no single equilibrium but several possible equilibriums, according to the alliances which are agreed upon between the participants..."

Precisely, it is opportune to refer here to this set of "alliances," explicit or implicit, which led to the modification of the existing equilibrium until the end of the 1960's, in order to reach a new equilibrium which, for the present, seems to be highly unstable and certainly will not attain stability for a few more years.

For this purpose we shall point out some aspects of the previous equilibrium, referring to [1] because it is one of the best analysis of the subject.

Adelman [1,p.224-225] points out that this rise of prices (he refers to the price rise of 1971-1972) was admitted by all the governments of the consuming countries, which for various reasons consider high international prices of oil convenient, since "if only the companies and the governments of the producing countries are considered, I would forecast without hesitation a continued and accelerated rate of decline of the prices of crude and its derivative. But the action of the governments of the consumer countries will tend, during the next ten years, to stop this decline of prices."

An important part of the analysis carried out by Adelman appears to be negated by the events of 1973-1974. Although we do not totally agree with his opinion, especially with the part that concerns the capacity of exporting countries to agree on levels of production and prices,[2] we think that his analysis (especially when considered over the long term) continues to be valid, and the deviations that are observed today are due to this political factor. This, in our opinion, is the fundamental element that explains the current situation.

Taking into account the characteristics of the equilibrium before 1970, it is possible to return to the problem of "relation of forces" among the participants and to stress that the increase of the oil prices in 1971, measured in standard currency, was basically the result of political rather than economic factors. The increase was, in part, owing to the pressure from OPEC to improve the income of the producing countries.[3] It also suited the interests of the United States which, in equalling the international with the internal prices, was able to open the imports and at the same time to increase the cost of energy in the competing developed countries of Europe and Japan.

Recalling the Adelman analysis about the interest of the

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[2]See [1,p.254]. Adelman admits to having committed an error when he thought in 1967-1969 that what happened in 1970-1971 was almost impossible. "But certainly I was much mistaken in thinking the chance of a threatened cut off was small." Evidently, events that took place in 1973-1974 showed once again the inadequacy of his new assumption.

[3]"It is clear that the pressure towards an increase of the current prices comes fundamentally from the joint action of the producer countries, who have enforced their rights to obtain higher incomes for the exploitation of their non-renewable resources; so as to increase the rate of their economic development and improve the just distribution of wealth all over the world, considering that up till now, the developed countries profited from the low prices of oil to promote their own development [3]."

governments of the consuming countries to maintain high prices for the oil, it is interesting to check the reactions of these countries in the medium and long term in the face of the "crisis." In almost all of these countries the totality of the price rise produced in crude oil was to a greater or smaller degree transferred without any reduction to the internal tax charged on oil products, in order to alleviate a process that publicly has been presented as "catastrophic." On the other hand, there were some concrete measures taken to diminish the consumption of energy over the medium term, which were proposed as highly restrictive (for example, reduction of the heating temperature to "only" 20°C, "maximum" speeds in highways of around 100 to 140 km/h); these might be considered scandalous if they are compared with the mean values prevailing in the Third World.

Finally, one may observe how countries have reinforced the development of alternative sources of energy which, as in the case of the United States, may help them to decrease their dependency on oil.

If we continue the analysis in terms of the game theory and the equilibrium of forces among the different possible "alliances" among the principal participants, we see that it is necessary to stress the reactions of the multinational companies and of the United States (supported by the other consuming countries) to the price increase of the producing countries for the first quarter of 1974.

Since the consuming countries considered these prices "too high," they have immediately acted to decrease them to levels which they deem "reasonable." Thus one could observe: a) the offers of the multinational companies to participate in the auctions of crudes; b) the initiative of oil producing countries, such as Saudi Arabia and Iran, to achieve the reduction of OPEC prices; c) the "warnings" and "threats" of the North American diplomacy with respect to this level of prices.

All this shows clearly that the present and future levels of oil equilibrium prices, and consequently of energy in general, basically depends on a balance of international forces. The particular interests of the main participants in the game have a greater influence on this attitude than do the physical considerations of costs of exploration, production, transportation, and energy use.

Finally, it is necessary to make clear the fact that in this work reference was always made specifically to the long-term tendencies, and the average levels over the long term which, for the United States, coincide with the values of the mid-1950's; this is the reason why the latter were taken as a point of reference.

If the level of international oil prices depended exclusively on the free play of offer and demand, in the long term it would have to return to the previous average levels, expressed in terms of constant currency. But, since reality does not match this scheme and the prices were, are and will be the result of an equilibrium of forces in the international arena, its future level will fundamentally depend on this equilibrium.

THE PRICE OF NATURAL GAS AT WELL HEAD

Basic Information

The information presented here is for the United States, although information on natural gas is less accurate and lacks the long history of oil and coal.

The Evolution of Prices in the United States

Figure 3 shows a variation in the real price that is much greater than the variation recorded for oil; the maximum is 86 percent greater than the average for oil and the minimum is 48 percent less. This may be explained by the fact that until World War II, natural gas was to a great extent a by-product of oil production, and its main uses were the consumption in the

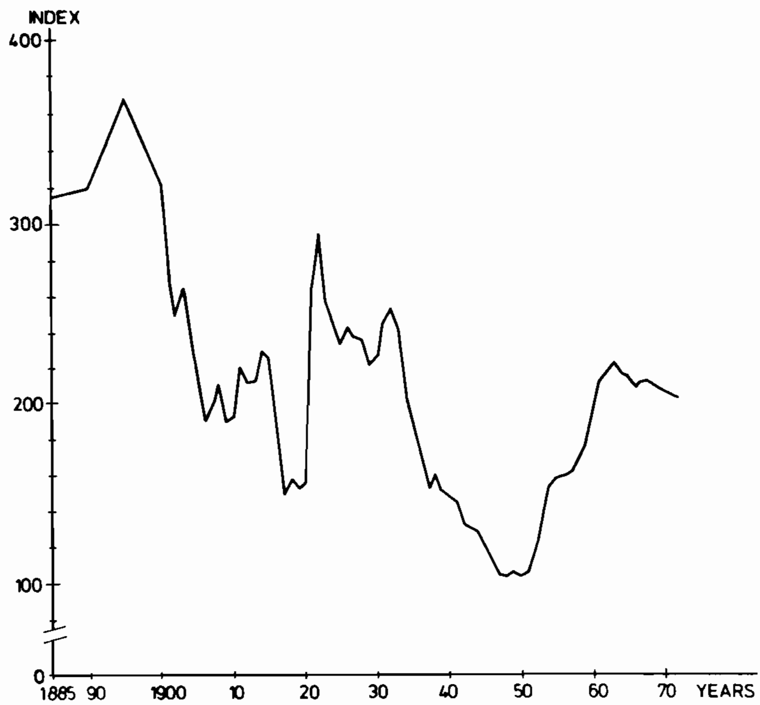

Figure 3. Evolution of the average price of natural gas at well head in the United States (1870-1972 period).

fields themselves, and raw material for the production of carbon black.[4]

In general, the variations of the real prices for natural gas follow a parallel evolution to those of oil, but with a markedly decreasing tendency until the mid-1950's.

During the 70-year period between 1885 and 1955, the real price of natural gas decreased to 50 percent of its original value. In this period one may note two great cycles of around 35 years each superimposed on the declining tendency; 1885 to 1920 is the first cycle, and 1920 to 1955 is the second.

Starting only in 1950, this declining tendency is altered and a new period of intensive growth begins, which in the course of 13 years brings the real price to a new maximum of 114 percent above the minimum level reached during the period 1947-1951; in any case, this level is still much below the earlier maximums recorded in 1895, 1922 and 1932.

This process takes place simultaneously with the intensive development of long distance transportation during these years; in this manner new and richer markets are opened for natural gas, where, in the face of competition the superior characteristics of this fuel can be valued.[5]

With the fall of the real prices of oil initiated in 1957, there is also a decrease in the real price of natural gas which, from the maximum value attained in 1963, decreases until it equals the average value resulting from the total of the historical records and with the values corresponding to 1934 and 1917 (see Figure 3).

It is worth emphasizing that this declining tendency occurs in spite of the fact that the data on reserves of natural gas show a decline in absolute values for many years; there is an intense argument about the possibility of a serious crisis of supply.

This detailed analysis of the evolution of the real prices

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[4]These two uses represented 50 percent and 40 percent of the total consumption in 1930 and in 1940 respectively, while by 1955 this value diminished to 20 percent. See [7, Tables 41 and 42].

[5]In 1945, the volume of natural gas transported between states accounted for only somewhat more than a quarter of the commercialized product, while in 1955, more than half of the commercialized production was interstate-transported [7].

in the United States shows that the price level is determined neither by the costs of production nor by the estimated degree of exhaustion of reserves; rather it is determined by other factors derived from the market or from government control, such as the level of prices of substitute fuels, technological development in the transportation of natural gas, the problems of pollution and/or the prices set by the state.

Future Evolution

The measures recently adopted by the Government of the United States as a result of tension between internal production and the increase in demand indicate that, in the coming years, a rise in the real price of natural gas may come about; this may become significant, on the order of 100 percent.[6,7] Thus, the tendency initiated in the period 1950-1963 would be repeated, with a consequent readjustment of the sectorial distribution of consumption; in this way the qualities of this fuel might be valued at a maximum compared to the substitutes (greater participation on the part of the residential and commercial sectors and of industries where quality of fuel is valued), and on the contrary, a lower proportion of the consumption at the fields and in thermal power plant.[8]

The Evolution in the International Market

The market for natural gas was developed much later in the main energy consuming countries of the world than it was in the United States and in general, after World War II; an international market of a great magnitude began to appear only in 1960 with the construction of the long-distance large-diameter pipelines and with the development of the transportation technique of LNG

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[6] The author forecasts an increase of 200 percent in the price of natural gas to be used in electrical power plants between 1970 and 1985. However, the increase would not be felt in the cost of electrical energy, due to the simultaneous decrease of the use of natural gas for this purpose [5,p.15].

[7] "Morrell supports higher crude prices," Oil and Gas Journal, August 14 (1972), p. 46. Several authors propose prices of the order of 45 cts/Mcft, in US dollars of 1970, in order to reach an internal production of natural gas and of oil, equivalent to 85 percent of total consumption.

[8] Forecasts for 1990 a participation of natural gas of only 1 percent of all the fuels used for thermal electricity generation [5,p.16].

(Liquified Natural Gas).

As in the case of oil, production costs of the great deposits of natural gas of the Middle East, Africa, the USSR and Europe are far below the prices prevailing in the main consuming markets of Europe, the United States and Japan.

The big differences in prices with respect to oil are determined by the fact that the potential profit generated cannot be absorbed by the producer and/or by the consumer countries as taxes, but must be assigned to cover the extremely high costs of transportation of natural gas, either by pipeline or as LNG or methanol.

When technological development produces a reduction in these costs, we can see the increased value of the production of natural gas (which until that time was allowed to escape) in the great producing areas and the use of reserves.

It would be misleading to consider the influence of the growing production costs (owing to a contingent exhaustion of the reserves) as a determining factor of greater prices of natural gas in the international market, where its present market "value" is zero in the great productive areas of the world. In this case, one may note a contradiction between the long-term tendencies and the current conjunctural situation. Thus, in the international market of natural gas, the prices have not risen at the same rhythm as those of oil, and therefore, the difference between the two instead of decreasing has increased. This is owing to the fact that normally the sales of natural gas are carried out through long-term contracts (approximately 20 years). Although it is true that these contracts have clauses of price readjustment, none of them could foresee the modifications recorded in 1973-1974 in the international oil market.

This situation also arises in the internal markets of different consuming countries since the governments, preoccupied with the consequences of inflation, do not allow pronounced increases in the price of natural gas; therefore, they must resort to compulsory restrictions to balance offer and demand. Evidently these abnormal situations will gradually disappear with time, and long-term tendencies will prevail. This fact explains the greater attention paid to them here.

THE PRICE OF FUELS AT THE LEVEL OF GROSS ENERGY AND USEFUL ENERGY

On analyzing the evolution of the real prices of primary fuels--oil, coal and natural gas--we have seen that, except in the case of oil, there exist diverse causes (not linked to the degree of exploitation of the total resources available) which lead one to foresee an increase in the real price in the middle term.

As a result of the predicted constancy for the real price of oil and of the increase of the prices of coal and natural gas, a modification in the contribution of each of these fuels to the satisfaction of the total demand of energy will have to come about; in this manner, coal and natural gas will have to orient themselves toward specific markets according to their technical characteristics.

On the other hand, an increase in the real average price of the totality of fuels per thermal unit supplied will come about which is in keeping with the past evolution of this value as it appears in the data given in Table 3 and Figure 4. We can see that, between 1870 and 1910, this average price was decreasing, basically as a function of the reduction of the prices of oil and natural gas. After World War I, there is a general readjustment of prices, which raises the average level to a value 30 percent higher than the previous minimum. Until 1945 there is a certain stability, as the fall of prices of oil and natural gas is compensated by the rise of coal.

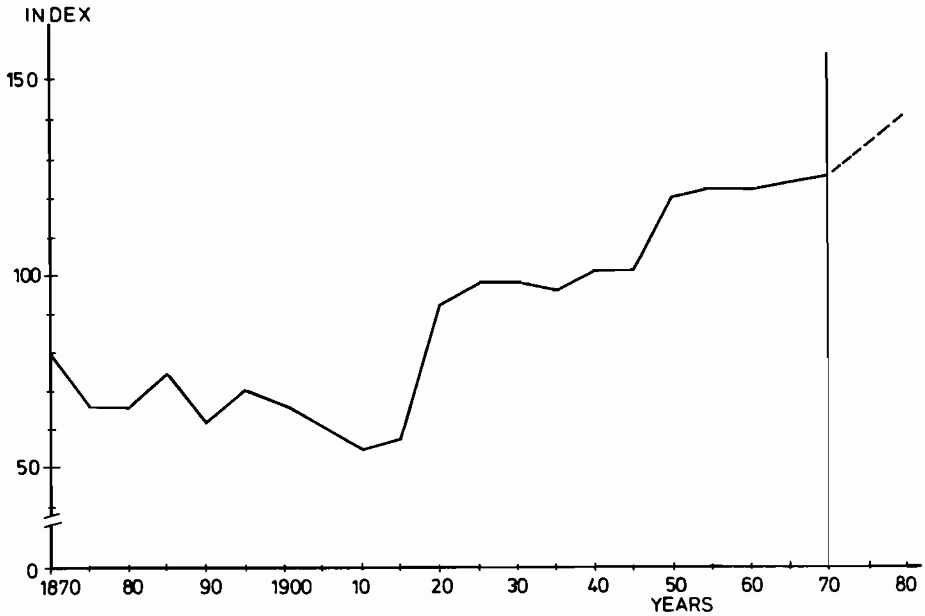

Figure 4. Evolution of the average price of the mineral fuels per unit of heat content, in the United States (1870-1970 period). Index relative to the general index 1947-49 = 100.

Table 3. Evolution of the average price of the mineral fuels per unit heat content in the United States (period 1870-1970).

Year	Average price standard currency cts dollar/10^6 BTU	Standard price index 1947-100	Index relative to the general index 1947-49 = 100
	(1)	(2)	(3)
1870	9.5	44.7	79.2
1875	7.1	33.4	66.2
1880	5.9	27.7	65.6
1885	5.9	27.7	75.4
1890	4.8	22.5	61.7
1895	4.8	22.5	71.0
1900	5.2	24.5	67.1
1905	5.7	24.0	61.4
1910	5.3	25.0	54.7
1915	5.6	26.4	58.4
1920	19.8	93.7	92.7
1925	13.9	65.4	97.7
1930	11.7	55.0	98.0
1935	10.6	49.8	96.0
1940	11.0	51.8	101.0
1945	14.8	69.7	101.0
1950	26.4	124.0	120.1
1955	28.8	135.0	122.0
1960	31.0	145.5	122.0
1970	37.0	173.8	125.0
1980	41.6	295.0	141.0

Sources: (1) Average price of mineral fuels per 10^6 BTU produced for the 1870-1955, column G Table MP-3, N. Potler and F.T. Christy, Jr., Trends in Natural Resources Commodities, page 316 is reproduced taken to cts/million BTU; for the period 1960-1970, estimates are based on existing data and structure of production of mineral fuels; for the year 1980, projections are based on theoretical prices estimated elsewhere and predicted structure of production, which includes a participation at the level of "yellow cake" of 5 percent of nuclear fuel and at a price of 6 cents/10^6 BTU.

(2) Index 1947 = 100 calculated on the basis of column (1).

(3) Relative index calculated by means of dividing the former by the general wholesale price index.

Between 1945 and 1950 a new jump is recorded, as a result of the rise of coal and oil, to a level 20 percent higher which remains approximately constant until 1970, thus compensating the rise of the price of natural gas with the fall of oil and coal.

Even though the level of 1970 doubles the values corresponding to the beginning of the twentieth century, it is necessary to take into account that the quality of the calories supplied has varied substantially,[9] since at the beginning of this century only 8 percent were hydrocarbons while in 1970 this percentage reached 74 percent.

On the other hand, during the century that elapsed between 1870 and 1970, the efficiency in the use of primary energy has also varied substantially; therefore, the price of energy used by the final consumer did not grow but in fact decreased significantly, as it can be seen in Table 4.

One may deduct that, from the point of view of the economic activity as a whole, the cost of energy consumed, measured at the level of production in 1900 was only 70.7 percent of that which the economy had to support in 1870; one hundred years later, it was as low as 43.8 percent.

Table 4.

Year	Index of prices 1947-49 = 100 (1)	Global efficiency of utilization % (2)	Index of prices of useful energy (3)	Index 1870 = 100 (4)
1870	79.2	10	792	100.0
1900	67.1	12	560	70.7
1947	103.7	30	345	43.5
1970	125.0	36	347	43.8

Notes: (1) Average price of the production of mineral fuels in the United States, Table 3, Column (3).

(2) The values of 1900 and 1947 are from Putnam in [7]. The values of 1870 derive from an interpolation and the values of 1970 and 1980 from an extrapolation of these values.

(3) (1): (2) x 100.

(4) Index 1870 = 100 of the data in column (3).

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[9] Trends in Natural Resource Commodities. This is due to a growing production of energy with higher quality fuels, which offered more advantages and economies to the consumer. As in 1957, the cost per BTU of the energy contained in oil was three times that of coal; the change in the proportion of the production of the various fuels explains the greater proportion in the growth of the index of the cost of energy.

Starting with World War II, one notices a stagnation in the improvement of the index, fundamentally because of a slower rate of growth in the global efficiency of utilization.

In the future, a tendency might develop which will be equivalent to the one during the period 1947-1970, or perhaps there will be a slight growth of the index, depending on what is the result of the different positive and negative factors that effect it.

The recovery of oil prices to levels, according to the long-term tendency and the increases in terms of coal and natural gas, will make the index grow. On the contrary, the incorporation of nuclear energy, whose cost per thermal unit is much lower than that of fossil fuels, will have an influence in favor of the decrease of the index.

Finally, as a result of the current "crisis," an important movement toward improving the efficiency in the production, transportation, transformation and use of energy can be already observed, which will provoke a substantial increase in the global efficiency of use, and therefore, a decrease of the index.

The role played by the technological developments in the achievement of the constant and even decreasing costs of energy appears clearly.

THE PRICE OF ELECTRIC ENERGY

Evolution of the Real Price of Electricity in the United States

We have again resorted to the average price per kwh consumed in the United States by all kinds of consumers, as is published periodically by Electrical World. The series is represented in Figure 5 (expressed in constant values). The available data cover the period 1920-1972, which in turn may be subdivided into two large sub-periods: 1920-1950 and 1950-1972.

During 1920-1950, a very intense variation of the average real price comes about, rising in a pronounced fashion until it reaches in 1932 a level 167 percent higher than that of 1920. This rise corresponds to the one produced simultaneously in the fuels used for generating electric energy, and to the economic crisis of 1930 which, as it is indicated by the prices from 1929 to 1937, had a notable influence because of the fall of consumption recorded during these years, and even more because of the consumption by the big industries (approximate fall of 30 percent between 1929 and 1932). For this reason, the average price of total sales rises, as the participation of the sector that pays lower prices is reduced.

From 1932 on, the tendency is reversed. There is a sharp fall in the average real price; this continues until the end of this first sub-period. This fall in prices is correlative to that of natural gas, which as we have already seen, begins to be used significantly more in power plants as fuel. Further influencing the tendency is the rapid development of the total sales during this period (9 percent annually, accumulative), and improvements in the thermal efficiency of the transformation of fuels to electricity.

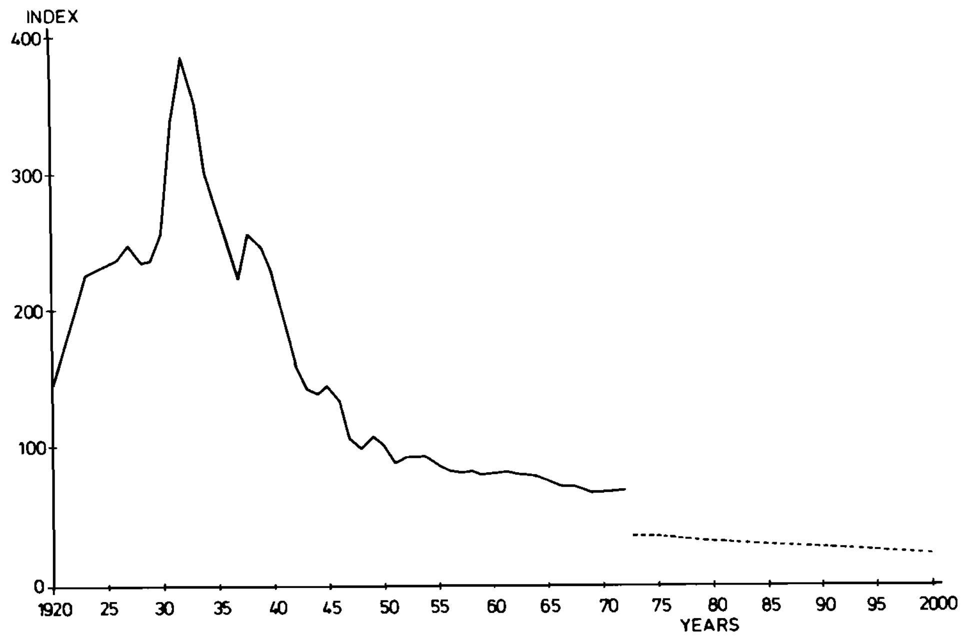

Figure 5. Evolution of the average price of electric energy per kWh sold in United States (1920-1972 period) Index relative to the general price index, 1947-49 = 100.

During the period 1950-1972, and beginning in 1950, there is a constant and sustained decrease in the real price of electric energy with great regularity in a linear rhythm of 15 index points every 10 years which if extrapolated backwards coincides approximately with the initial level of 1920. This evolution of the last 22 years is the result of a combination of factors: diminishing prices of some fuels, mainly coal; improvements in thermal efficiency; economies of scale in a growing market.

Future Evolution of the Costs of Electric Energy

When one moves on to predictions, one necessarily considers the aspect of production costs, rather than that of prices. But this does not fundamentally change the analysis, since for electric energy, prices are strongly determined by production costs.

There is much literature on the subject, and we refer to the data of Myers [7].

After analyzing world consumption of energy and available resources, and discussing different programs now in effect to develop fast-breeder reactors and nuclear fusion, Myers gives a detailed series of data on the estimated evolution of the costs of generating electric energy for each of the lines of reactors in use and in development for the next few years until the year 2000, and finally reviews the evolution of production costs in conventional thermal and nuclear generating stations for the period of 1972 and 2000.

If, for each of the years indicated in Table 5, one takes a simple average of the values presented, the following results are obtained:

Table 5. Cost of production of electricity.

Year	US Cents/kwh Constant value of 1972	Index relative to the General Price Index 1947-1949 = 100
1972	0.97	36.4
1975	0.93	35.2
1980	0.82	31.0
1990	0.72	27.2
2000	0.59	22.2

One may note a clear falling tendency at an average annual accumulative rate of 1.75 percent, similar to the tendency noted in the average real price of electricity in the United States. Thus we can state that the falling tendency in electricity prices recorded in the past will continue in the future; although in the middle-term (1980-1985) the rise in fossil fuel price may check this tendency temporarily, until nuclear power plants provide a significant proportion of the total production.

Final Comments

The case of electricity reflects the influence of technological development in the lowering of real prices of value produced since there is no problem of exhaustion of natural resources as is the case with fossil fuels. Thus, when a certain energy source becomes more scarce or expensive, it is replaced by another and the diminishing tendency in the prices continues.

With respect to fuels, technological development in all stages of production, transportation, transformation and utilization has permitted the maintenance of, and a significant decrease in, the real prices of useful energy in the past. Therefore, it seems reasonable to consider that in the future prices can be maintained at present or only slightly rising levels. On the contrary, the tendency of electricity, past and future, is clearly one of lowering prices.

Taking into account that both middle- and long-term predictions forecast a continued increase in the proportion of electricity in the overall energy consumption, it does not seem bold to assume that the real price of energy supplied to the international economic system will not go above its present levels.

REPERCUSSIONS OF THE CONJUNCTURAL SITUATION

Even though not directly associated with the question of the evolution of prices, it seems worthwhile to state the problem and to study, even if briefly, who benefits and who loses as a result of recent developments in oil market prices.

It is beyond doubt that these developments directly benefit the oil producing and exporting countries, which receive a substantial increase in financial resources, even taking into account the general rise in prices of manufactured goods[10] and of other raw materials which they must import. (This rise was produced simultaneously as a reflection of world-wide inflation. According to a World Bank study, in the period 1967-1969 to 1974 the global price index of raw materials rose from 100 to 244, while oil rose from 100 to 665.)

It is also necessary to point out that the group of oil exporting countries represents only 7.2 percent of the world population (and only 2.3 percent if Indonesia and Nigeria are not included in the group).

One may already observe the measures being adopted by the developed countries to recover an important part of these resources; among other: arms sales, creation of financial mechanisms, the sale of equipment and technology for investments in the producing countries. At the same time, numerous arguments are made to justify the massive transfer to the producing countries of refineries, petrochemical and iron and steel plants, and the like. As a result of these transfers, markets of developed countries are broadened, thereby solving in part their problems of industrial location and pollution.

The great multinational companies passed on the price increases in an incremented form that allowed them to greatly

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[10] Recently, Mr. Boughera, Vice-president of SONATRACH, during a seminar organized by the I.E.J.E. of the University of Grenoble, mentioned that the cost of an installation for liquefying natural gas had quadrupled during the period 1970-1974.

increase their profits in 1973; moreover, they have recovered a large part of their capital invested in oil. Thus they have been able to reinvest, for example in the United States oil industry or in other energy sectors, thus achieving their objective of transforming themselves from oil companies to energy companies. Also, there are countries that are not oil exporters, but are producers of oil and/or possess other energy resources which can be valued, given the rise in oil prices. Basically these are the United States and the USSR; other intermediate countries include Argentina, Australia, Brazil, Canada, Mexico and Romania.

Those damaged by the increase in oil prices can be divided into two groups: Europe and Japan among the developed countries; and those Third World countries that are not oil producing countries, at least not producing quantities sufficient to supply their own needs. This latter group may benefit from the price increases in other raw materials which they export; however, they have to face an increase not only in oil prices, but also in manufactured goods, other raw materials and food products. This latter group includes the majority of the world's population (33 percent, excluding China), which also has the lowest levels of development.

In conclusion, the developed world suffers from a certain modification of relative prices, and loses some of the advantages accumulated over the last 10 to 20 years. However, it is still in a position to recover easily from the effects of these modifications. A small group of the Third World countries is in a position to benefit directly and substantially, but the great majority of the Third World finds itself even more submerged than before.

CONCLUSIONS

We will point out the main conclusions that can be drawn from the study; the order in which they are stated in no way implies a classification of their importance.

Conclusion 1. The current price of oil in the international market (oil being at present the primary energy source) is to a great degree higher than the real production costs in the main supplying areas of the international market (especially the Middle East and Africa).

Conclusion 2. This high price of oil, which was earlier related to the internal costs of production in the United States seems currently to be more related to a higher value--that is, in line with the marginal production costs of alternative sources of energy (natural oil, oil-bearing shales and tar sands, oil and natural gas derived from coal) in the United States, so as to allow the United States to recover its energy independence. This situation generates a differential profit, which the producing and the consuming countries obtain through taxes and royalties and the multinational companies through large profits.

Conclusion 3. It could therefore be stated that if the international price of oil were determined only by the supply and demand in a market of pure and perfect competition, it should decrease substantially, as it is affirmed by M.A. Adelman [1].

Conclusion 4. Since it is in the interest of both the producing and consuming countries (at least in the case of the United States) that the above not happen, it can be predicted that over the middle- and long-term, the real price of oil in the international market will continue to be at levels similar to the historical ones.

Conclusion 5. The real prices of coal and natural gas might undergo a certain increase: in the first case, to the extent that the technological progress does not compensate for the higher costs brought about by new conditions of production; and in the second case, until oil again takes its place in the substitutive mechanism among energy sources.

Conclusion 6. Regarding the real price of electric energy, it does seem possible to state that it will continue to decrease in the future as has been the case. This is very important, since all experts agree that around the year 2000, nuclear energy will supply about one half of man's need for fuel for the production of electricity, which in turn will represent about one third of the total of consumed energy.

Conclusion 7. As a result of the above mentioned partial modifications to the change of structure in the contribution of the different sources of energy to the total consumption, and of the improvement in the efficiency of energy utilization, we can state, that the real average price of energy as useful energy will remain constant in the long-term, although there may be a slight increase in the middle-term which will then return to the declining tendency.

Conclusion 8. The technological development applied to all of the levels of production, transportation, transformation and utilization of the various forms of energy is fundamental for the achievement of the predictions pointed out earlier in this paper, and therefore the support provided by research and development work is of great importance.

Conclusion 9. In the determination of the level of energy prices, the analysis carried out shows that the group of measures of economic and social policies adopted by the different countries of the world and the rate of technological development is much more important than the degree of utilization of the energy resources of the world.

Conclusion 10. The energy crisis, which first developed in the United States and had its repercussion later in the international sphere starting in 1967-1969, may be considered as possessing conjunctural characteristics, as others of similar importance which occured in the past, and we can already perceive the main reactions of the system aimed at re-establishing a new equilibrium which, on the average, will not differ substantially from the long-term tendencies.

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Discussion

Peter Fleissner, Rapporteur

Curnow opened the discussion of "Non-renewable Natural Resources and Pollution Methods", asking whether the transformation from the status quo to the situation described by Herrera could be achieved in a peaceful way. Is the model real? What about the influence of the multinational corporations? Should an international agency control resources? Herrera replied that we do not know whether transformation can be peaceful or not; this will depend on the attitude of the people and the countries involved. Developed and developing countries now follow the same rules: buy cheaply and sell at a high price. If an international agency controlled world resources, the influence of the most advanced countries would be very great.

Mottek commented that compared with the MIT model, the Bariloche model drew optimistic conclusions. But there was much uncertainty. Real crises of shortages of resources have existed throughout history. In the 14th century, for example, there were shortages of silver that were resolved by the discovery of America and the development of the new technology of mining. The shortage of wood that occured in the eighteenth century lasted several decades. Large time lags between a shortage and solution to the crisis could appear. The prices given in the paper could be misleading. They are relative prices only. The proportion of the prices have changed: In the past, prices of raw material rose with respect to other prices; with colonial expansion they fell. The Bariloche Model implies more rapid technological progress in the resource sector than in other sectors, which is probably not the case in the long run. The question of raw materials could bring about struggles for access to the sea, of these some are already taking place. In closing, Mottek proposed a standard run that would show the most likely behavior and the variations with respect to certain goals.

In Herrera's opinion, pessimism or optimism was a psychological and not a scientific question. The model considered bottlenecks worldwide, Europe being only a small part of the area considered. Some bottlenecks were lasting, but very often there were substitutes. The critical metals used now to a large extent are not geological bottlenecks. He was speaking only of geological, and not of political problems.

McPherson said that his optimism was tempered with respect to energy equations. One should consider the inefficiency of combustion engines, in which only five percent of the energy potential of oil is used. He believed that the production of food is increasingly energy-consuming. The search for alternative energy is as desperate as ever.

Iyengar shared the optimism of the Bariloche group, but said that other problems exist. The former colonial countries were selling their raw materials in the same manner as before. If prices rose, developed countries would use energy resources more carefully. Also, new technologies should be sought.

Roberts pointed out that it was not easy to find substitutes for certain materials. Thermal pollution could occur. Ice caps could melt.

Herrera believed that the level of the United States energy consumption will spread to the whole world, and a temperature change of between +0.5 and -0.5^{0}C could occur. While some regulation mechanism existed, he did not see any difficulties in this area.

Attention was focussed on "The Long-Term Evolution of Prices of Energy".

Deuton stated that he expected the bottleneck to occur within the next 15 years. In the long term there would be a decline in energy prices, and a more optimal price would be set by the Organization of Petroleum Exporting Countries (OPEC). New techniques, for example solar energy, would be available after the year 2000.

Suarez responded that the problem was not whether the price would rise, but when. While there was a crisis now, there would be none over the long run. The price rise was the result of policies of OPEC and of international corporations. Nuclear power plants posed potential problems in the event of war. Solar energy would be clean.

A second commentator said that prices in the oil market were manipulated; they were about 100 times higher than the costs of production. This had little to do with economic and technological forces. If other new institutions similar to OPEC were founded, prices would rise.

Suarez replied that the rate of inflation was very high in developed countries. Plants built by developed countries were now very expensive.

Replying to the question of how the evolution of prices was implemented in the mathematical model, Scolnik said that the proportion allocated to energy was limited. Herrera added that there was a sharp difference between prices and costs. Short-term price evolution was not predictable, but in the long run prices were related to cost.

The Food Sector

Gilberto Gallopin

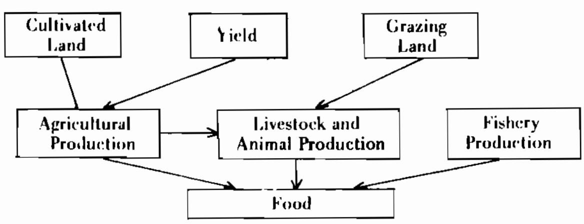
INTRODUCTION

The objective of this submodel is to describe the structure of relations between the main variables involved in the food production system, their functional form, and their approximate numerical value, in order to calculate the capacity of each block and the world as a whole to provide sufficient food for their population.

In view of the considerable uncertainty of the available data and the complexity of the system, in all instances the most pessimistic of the sensible alternatives available have been chosen. This strategy should insure that over-optimism is not present in the model.

The food system is viewed as composed of three subsystems: agriculture, livestock and terrestrial animal production and fishery. A fourth subsystem, non-conventional food production, which would have included algal and bacterial culture, mariculture, direct protein synthesis, protein purification from non-edible plants, and the like was finally eliminated from the Model. We took into account that it is a complex set including very different processes, and that most of the available information comes either from laboratory experiments or from theoretical extrapolations. (There are very few reliable data about the operation of these processes at the economic or industrial stage.) Also a subsystem does not appear necessary to provide the food requirements of the population of the world. Thus the exclusion of this sector is a pessimistic hypothesis.

The main divisions of the food sector appear in Figure 1.



Note: Economic variables not included.

Figure 1. Basic divisions of the food sector.

Food production is not considered in the Model, as a profit-making enterprise, but rather as an essential service. The main consequences of this assumption are as follows:

- the land is owned by the society, and therefore it has no monetary value;
- agricultural inputs are made in the region, despite the possibility of cheaper costs of imported inputs;
- livestock and terrestrial animal production is fed from the grazing [non-arable] land and from the non-edible portion of agricultural production - that is, the agricultural production that can be used as food for man is not used to feed animals;
- livestock and animal stock is owned by the society, and has no monetary value; and
- the operation of the agricultural, terrestrial animal and fishing processes is rational and society-oriented, implying social planning and the application of land and water protection policies, as well as attempts to provide adequate communication, transportation, distribution and education infrastructure.

THE AGRICULTURAL SECTOR

The agricultural sector is the most important sector of food production, either in terms of its present share of the total production, or in terms of its potential in the near and foreseeable future. Given that the Model assumes current technology, agriculture is assumed to be based on the land. Not all land is potentially arable land, under present technology. Land can be unsuitable for agriculture because of adverse climatic conditions, slope, soil characteristics, urbanization, etc. A main variable of the food sector is the available land that can be put under cultivation, and a given technological level--that is, the potentially arable land.

POTENTIALLY ARABLE LAND

The definition adopted is the one given in [1]: potentially arable land is defined as including soils considered to be cultivatable and acceptably productive food crops adapted to the environment. Agricultural technology equivalent to the average United States (1967) agricultural technology is assumed. Soils already under cultivation as well as other soils not currently cultivated are included. Some soils will need irrigation, drainage, stone removal, clearing of trees or other measures, the cost of which would not be excessive in relation to anticipated returns. The estimations of reference [1] were utilized. The arable land can increase as more land is put under cultivation, and can decrease by land degradation.

LAND DEGRADATION

Land degradation can be caused by the following:

1) reduction of soil fertility;

2) soil erosion; and

3) urbanization.

The main fertility problems that can be associated with intensive agriculture are the loss of humus, soil compactation by use of heavy machinery, soil salinization and soil water logging. While there are many examples of soil fertility degradation associated with intensive agriculture, most of them seem to be attributable to incorrect management practices [14,15]. Thus, soil fertility degradation seems to be a consequence of irrational agriculture, rather than of intensive agriculture. It is possible to have intensive agriculture together with soil fertility maintenance or even increase. Many of the necessary measures are not related to cost, because it is a matter of rational management.

In the Model, a cost of soil fertility maintenance is assumed, as a fraction (10 percent) of the agricultural inputs applied; this soil fertility degradation is not a physical factor in the model but an economic one.

Soil Erosion

In natural conditions, in general, soil erosion proceeds at a speed of the same order of magnitude as soil formation.

Erosion can be accelerated by the disturbance of the natural landscape, usually by man, and can result from exposure of the soil to runoff through burning, excessive grazing, forest cutting, and tillage. Exposed soil may erode very rapidly if it is not managed according to its limitations and requirements. Historically, there are many examples of man-accelerated erosion, including the desertization of important areas by non-restricted forest cutting, overgrazing, inappropriate irrigation [14,27]. Most examples of accelerated soil erosion can be attributed to deficient management and to lack of protective measures, rather than to an unavoidable consequence of agriculture or cattle raising [14,15,17,18,30].

The adequate management of soils can drastically reduce, eliminate the erosion, or even recuperate soil extremely eroded. It is very difficult to estimate the cost of soil erosion control, because many measures imply only decisions on cultural practices, or imply measures which diminish cost (reduction of overgrazing and burning, retention of crops residues, etc.) Other measures imply a cost such as terracing of the landscape, construction of small dams, fertilization, flood control. The measures to be taken depend upon the soil type and erosion risk.

In the Model, it is assumed that the cost of effective erosion control is, of the order of 5 percent of the cost of agricultural inputs applied.

Urbanization

Another source of land degradation is urbanization that is, the construction of houses, cities, roads, highways, airports, etc. Historically, an important fraction of urbanization has been located upon flat terrains, with available water and near cultivated areas. This implies that probably a high percentage of urbanization has taken place on potentially arable land. In the food sector, the urbanization rate is an input from the urbanization sector. Only a fraction of the urban area is built on potentially arable land. A rational society should attempt to diminish the fraction of urban area installed upon potentially arable land. In the Model, it is assumed that 50 percent of the new urban is built on potentially arable land, as a pessimistic hypothesis.

This kind of land degradation is considered irreversible in the time-horizon of the Model. Therefore, the land degradation rate, assuming soil fertility and erosion control is the same as the rate of urbanization on potentially arable land. (It is assumed that urbanization does not take place on currently cultivated land.)

The potentially arable land available in a given year is the potentially arable land of the preceeding year, minus the potentially arable land built on.

The area available for further expansion of the cultivated land in a given year is the difference between the potentially arable land and the land already under cultivation.

Land Development

The arable land can increase by developing new lands, up to a limit imposed by the potentially arable land available. The development of new lands is made at a cost, and therefore depends also on the economic resources available.

In the Model, the arable land in a given year is considered a function of the land available in the preceding year, the current rate of land development and the current potentially arable land.

The land development rate is assumed to be a function of the unit cost of land development, and of the economic resources available for development.

Unit Cost of Land Development

A separate analysis was made of the unit cost of development of new land only, that is, excluding the projects for amelioration of land presently cultivated. A summary of the data appears in Table 1. There is a suggestion of a slightly increasing trend in the mean unit cost of development of new lands for Asia. However, when analyzed statistically, the mean unit costs are not significantly different by using both the Student-t test and the non-parametric Mann-Whitney's U test. (The probability that the means come from the same population is greater than 0.20.) On the basis of the data analyzed, we have rejected the hypothesis of an increase in unit cost of land development as the fraction of the potentially arable land remaining decreases. On the other hand, there is evidence of the existence of a phenomenon of economy of scale, of a decrease roughly exponential of unit costs as the total size of the project increases. A detailed analysis has been made, but it is not relevant here. The only important points are that a mechanism of unit cost reduction seems feasible by manipulating the size of the project and that the data points from different regions behave similarly, thereby justifying the use of a global function.

In the food sector, a deliberately pessimistic hypothesis was utilized, assuming that, contrary to the evidence studied, the unit cost of development increases exponentially with diminishing remaining fraction of potentially arable land, up to a maximum of \$6,000/ha, and a minimum of \$1,200/ha.

Table 1. Unit cost statistics of development of new lands for different projects (dollars per ha).

	South America	Asia	Africa	Australia	North America	Total
N	8	5	2	1	1	17
X	1,149.1	1,638.6	1,114.5	62	1235	1,230.1
S	1,327.26	1,223.94	815.29	-	-	1,152.88
CV	115.5	74.6	73.1	-	-	93.72

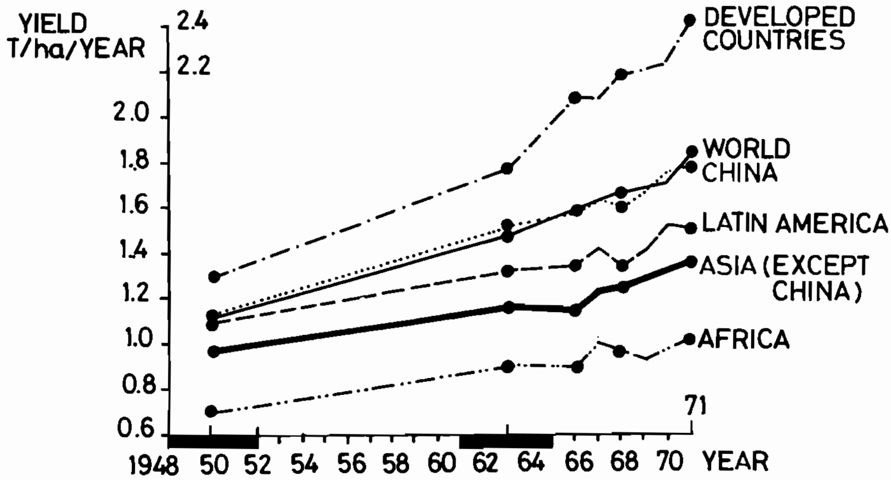
AGRICULTURAL YIELDS

The yield of agriculture is the fraction of the plant productivity that can be used as food for man. Plant productivity, and therefore, agricultural yields, depend on many factors: solar radiation, temperature, water, carbon dioxide, soil nutrients, the species of variety of plant, etc. In practice, any of these factors can deviate from the optimal value and therefore limit the yield. Any of these factors can be optimized, in theory; however, in practice, some corrective measures are more expensive than others, or even the technology to correct some factors may not be available.

There is evidence that modern agriculture is much more independent of local environmental conditions than primitive agriculture, and it is likely that this independence will increase as agriculture becomes more and more similar to a typical industry. This is also indicated by some studies, namely those of FAO [47] and Brown [48]. It is widely recognized that the technological level of agriculture is a more important determinant factor than local environmental conditions, for a wide range of regions, at least for yields below the potential productivity values.

Real Agricultural Yields: Space-Time Evolution

Agricultural yields have increased dramatically in the present century, and they seem to continue to increase. However, the rate of increase has been differential, growing more rapidly in the developed countries. Figure 2 shows the aggregated yield of cereals for each block of countries from 1948 to 1971.



Source: [7]

Figure 2. Aggregated yields of cereals for different areas (1948-1971).

It is interesting to note that the ranking of regions in terms of yield is the same that could be obtained if the ranking were ordered according to GNP per capita (GNP per capita for China is not estimated in the UN Statistical Year book). It is important to note that these are not maximal yields, but rather global yields, calculated by dividing the sum of total cereal production for each block by the total areas allocated to cereals.

For the Model, food production in terms of weight, calories and weight of protein was necessary. The statistics given by FAO [2] indicate the production in terms of weight; a conversion factor for each main crop weight to calories and proteins was used by using various sources [56,57].

For each crop, FAO's estimations of production (in weight) and area of the crop were used. The sum of production for all crops for a block of countries, divided by the sum of areas cultivated with the crop, was considered the aggregated yield in tons/ha. For the other units of yield, the production of each crop for each country was treated similarly, after multiplying the appropriate factor of transformation to calories or proteins.

The actual values of aggregated yield, in tons of edible fraction of crop for 1970, for each region, appear in Figure 3. The band indicated as potential yield of crops was obtained by taking into account different estimations of the maximal yield of food limited by climate and light only [21,23,52,53,54,55], with a median of about 30 tons/ha. Note that actual yields much higher than those indicated by Holland already exist, because the values indicated are global for a whole country or region. The figure shows that actual yields for blocks, and even for the most efficient countries, are far below the ones theoretically possible (note that the axis is logarithmic.)

Agricultural Yields as a Function of Identified Agricultural Inputs

Under the hypothesis that aggregated yields at the level of a country are related directly to the level of technology, which is supposed to be indicated by the agricultural inputs applied, an exploration of the relationship among yield and inputs was undertaken. For the purposes of the present Model, it was necessary to relate yield to the identified agricultural inputs for which world wide statistics are available. The identified agricultural inputs were obtained from FAO [2]. Also, agricultural population or population economically active in agriculture was considered an input. The inputs considered are: fertilizers, pesticides, tractors, agricultural population and population economically active in agriculture.

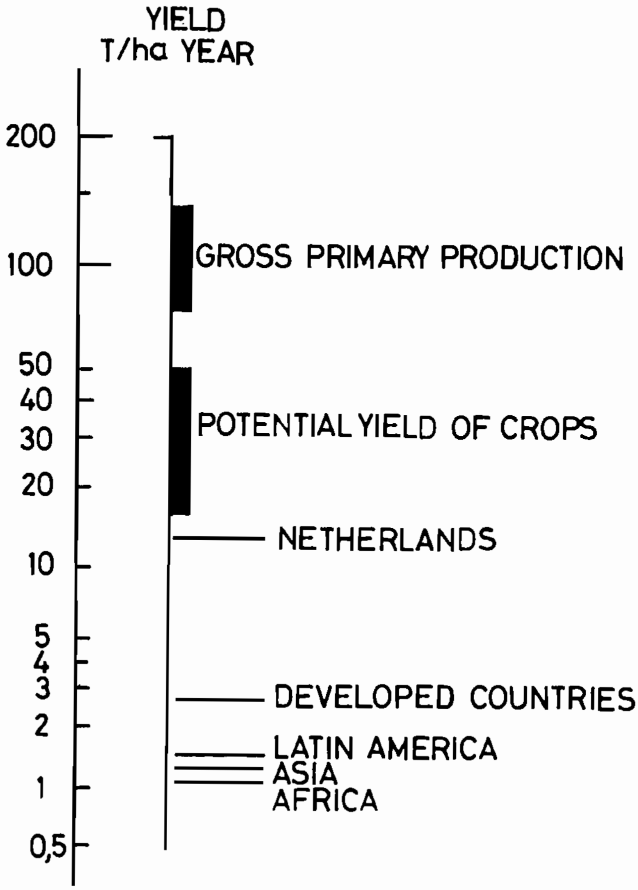


Figure 3. Aggregated agricultural yields (edible) for regions, 1970, compared with the estimation of potential yield of crops, and gross primary production. Logarithmic scale.

The analysis of the data on agricultural inputs does not show strong cross-correlations among them, with the exception of fertilizers consumed per ha. and tractors per ha., with a suggestion of a growing trend in the density of tractors with the consumption of fertilizers, with a correlation coefficient of 0.77, and stabilizing in the order of 120-160 tractors/ha. Naturally, there is a good lineal correlation between agricultural population and population economically active in agriculture (R=0.96). Other inputs show weak correlation among them.

Previous studies [59] indicated that fertilizer consumption is a good predicator of yield for cereal crops for 40 countries, in the period 1956-58. Also, fertilizer consumption is one of the inputs better documented by FAO, and theoretically can be considered one of the more important inputs, if accompanied by the appropriate technological and cultural practices. Besides, the degree of use of artificial fertilizers can be considered a good indicator of the adoption of efficient agricultural practices [59].

Different equations were fitted to the data of aggregated yields of countries versus fertilizers consumed. Theoretically, hyperbolic and exponential equations were considered to be justifiable; the empirical square-root equation used by William and Couston [59] was also fitted. The equations were fitted to data consisting of yield in tons of crop per ha. kilocalories per ha., and tons of proteins per ha., for all countries and for three periods: 1948-52, 1965 and 1970. The three equations provided a fair fit to the data, but the exponential was better than the others in a majority of cases.

The possibility that the other agricultural inputs would add statistical explanation besides that provided by fertilizers was considered. An analysis of residuals [61] (the difference between calculated and real yields) was performed, and showed that taking into account the other agricultural inputs do not add statistical explanation to that provided by fertilizers. The possibility was considered that GNP per capita, as a general indicator of the economic level of the countries, would add statistical explanation; the examination of residuals indicated no effect. Also, an attempt was made to attribute part of the unexplained variation to environmental conditions. Lieth's map of gross primary productivity of the earth [50] was used as a rough indicator of main climatic factor. Again, the examination of residuals did not show evidence of any effect.

The apparent lack of relationship between yields and density of population economically active in agriculture, which could be considered theoretically as an important factor, is probably owing to the following. First, it seems likely that agricultural population is not at present a limiting factor in any country, and its value is generally on or above the optimal value. Secondly, different strategies are utilized in different countries in relation to the use of labor and inputs. Some countries have chosen to reduce labor through mechanization, and in many countries agriculture is much more labor-intensive. Those differences in strategies are not consistent even within developed countries. In any case no effect from the population economically active in agriculture [which is, itself, only a very rough indicator of agricultural labor] upon yields can be detected from the data, and, therefore, labor was not included in the yield function.

The proportion of yield variation attributable to fertilizers is of 78, 79 and 72 percent, respectively, for yields expressed in tons of crop/ha., 10^6 kilocalories/ha., and tons or protein/ha.

Table 2 shows the global yields calculated for each block. The data for blocks and for the world are well within the limits of variation of the data for countries, supporting the validity of using a unique equation to describe the functional relationship between yields and fertilizers, for countries as well as for blocks. A direct fit to the data for blocks would be meaningless, because of the small number of data points.

Table 2.

Region	Year	Fertilizers (Kg/ha)	Yield (T/ha)	Yield (10^6Kcal/ha)	Yield (TProt/ha)
Developed Countries	1948-52	22.89	1.84	4.70	0.14
	1965	54.23	2.35	6.48	0.21
	1970	78.86	2.70	7.61	0.25
Latin America	1948-52	3.30	1.11	3.40	0.11
	1965	15.24	1.27	3.99	0.14
	1970	20.69	1.55	4.89	0.17
Asia	1948-52	1.17	1.08	3.36	0.11
	1965	4.46	1.19	4.06	0.14
	1970	18.59	1.33	4.55	0.15
Africa	1948-52	2.75	0.89	2.46	0.08
	1965	3.71	1.04	2.92	0.10
	1970	7.23	1.12	3.22	0.11
World	1948-52	13.34	1.41	3.89	0.12
	1965	27.75	1.64	4.91	0.16
	1970	45.07	1.84	5.61	0.19

According to the above discussion, the exponential function fitted to the yield versus fertilizer data for 1970 for all countries, was selected as yield function. However, a pessimistic hypothesis was included, by allowing a maximum yield of less than one half the maximal current aggregated yields for countries. By using this function, an implicit assumption is that relative crop composition remains fixed in the 1970 values, which is a pessimistic hypothesis, given that one way to increase yield for a fixed input level is manipulating crop compositon favoring the more yielding kinds of plants, and diminishing food diversity.

Cost of Agricultural Inputs

The costs of agricultural inputs are difficult to estimate particularly because of the requirement that inputs are made in each block, instead of buying them at market prices.

The fertilizer costs used here are the costs to develop fertilizer production facilities in developing countries, which greatly exceed those for similar facilities in developed nations, as estimated by [1]. FAO [4] estimates that the capital investment to provide a demand of 26×10^6 tons of fertilizer is of the order of 12,000 x $\$10^6$ for developing countries (that is about $460 ton). Those figures are more than twice the price paid by farmers in 1970, according to FAO [2]. Given the potential for ameliorating the fertilizer technology, and the effect of the economy of scale, the real cost could be much lower than the above estimations [4].

While fertilizer is an important agricultural input, all production inputs should be used in the proper proportions to maximize yields. It is difficult to evaluate the proper proportions of other inputs, and the relative costs.

The calculations of the relative cost of fertilizer, improved seeds, and pesticides were obtained from the estimations made by [1] being presented in the form of capital investment needs to increase production in various proportions in developing countries, for each of the inputs. The estimated capital costs for fertilizer is more than 93 percent of the total cost of fertilizer, seed and pesticide needs. Mechanization (not included) is an input which can be substituted for labor to a great extent.

On the basis of the above discussion, it was decided to include all agricultural inputs besides fertilizer as a fixed proportion of the total capital available for agricultural inputs. This fraction was assumed to be 20 percent of the capital cost of agricultural inputs, that is, 13 percent more than it would be indicated from the estimations of Table 3.

In the Model, the economic resources available in a given year for increases in agricultural inputs are distributed in a fixed proportion to agricultural inputs other than fertilizers, to erosion control, and to soil fertility control. The remaining economic resources are allocated to implement additional fertilizer production.

The increment in fertilizer production, in a given year, depends upon the economic resources available and the unit cost of fertilizer production.

Table 3. Estimated capital investment costs for improved seeds, fertilizers, and pesticides to increase agricultural production in developing countries.

% Increase in agricultural production	Capital investmens ($$10^6$)			Total capital ($$10^9$)	Capital for Fertilizers as % of total capital
	Seeds	Fertilizers	Pesticides		
0					
10	30	2500	100	2.63	95.1
20	60	5000	240	5.30	94.3
30	90	7500	380	7.97	94.1
40	120	10000	540	10.66	93.8
50	150	13000	710	13.86	93.8
60	180	16000	910	17.09	93.6
70	210	20000	1150	21.36	93.6
80	240	23500	1410	25.15	93.4
90	270	27000	1670	28.94	93.3
100	300	30500	1910	32.71	93.2

Cultivated Versus Arable Land

Not all arable land is cultivated every year for major food crops. Part of the land is left fallow, and part is cultivated with non-food crops and with miscellaneous food crops. An analysis of the data for 116 countries, for 1970, indicates a linear relationship between cultivated area under major crops and arable land and land under permanent crops.

The global ratio of land under major food crops to arable land and land under permanent crops was calculated for each block, for the data for 1970.

The figures show that, with the exception of Asia, all blocks have the potential to duplicate the area cultivated with major food crops, without extension of the arable land, on detriment of non-food crops and fallow land, if the necessity arises. To use as fixed the 1970 proportions implies, then, a pessimistic hypothesis.

Post-Harvest Losses

The agriculture submodel utilizes real yield obtained by the countries, instead of potential yield and therefore pre-harvest losses are already included in the calculations. However, post-harvest losses need to be considered. Post-harvest losses include all losses that appear between harvest and sale to consumers. The major components are due to losses during storage, processing, transportation and distribution.

It is extremely difficult to estimate the post-harvest loss of food [64]. Different estimations cover the range from 10 to 50 percent of the world production. On the basis of an analysis of a number of estimations, it was decided to assume a post-harvest loss coefficient equal to 10 percent of the food produced, for the developed countries, and equal to 30 percent for the underdeveloped countries.

It was decided that it would be realistic to assume that post-harvest losses in the underdeveloped countries would tend to reach the value for developed countries as the general economic situation improves through time.

Notice that post-harvest losses in the Model never become smaller than 10 percent, which is a pessimistic hypothesis, considering that technically it is now possible to reduce them to lower levels.

Agricultural Food Production

Agricultural food production is defined as the portion of agricultural production that can reach the consumer level; it is, therefore, the total agricultural production, from cultivation of land for major crops, after the post-harvest loss is subtracted.

Allocation of Economic Resources within the Agriculture Sector

The economic resources available in a given year for agriculture are allocated optimally to land development and to agricultural inputs.

LIVESTOCK AND TERRESTRIAL ANIMAL PRODUCTION

Livestock and terrestrial animal production (abbreviated as "livestock" from now on) includes here the production of meat from beef, pork, mouton, goat and poultry, but excludes wild animals.

Proteins from animal sources are high quality because they are composed of relatively large amounts of the essential aminoacids. However, it is important to mention that plant proteins can easily be fortified by adding the limiting aminoacids or proteins concentrates to improve the nutritive value [1]. There is no doubt that human diet can be adequately supplemented with properly processed oil-seed meals, microbial protein, and synthetics [1]. Therefore, in the Model, no distinction is made between animal and plant proteins; the latter are assumed to be fortified.

However, strong preferences have developed for animal products, and they will probably continue to have economical demand [1]. The present situation shows that the effects of this demand can be quite irrational in terms of the satisfaction of global food needs; in many developed and some underdeveloped countries, animals are fed cereal food, which would be otherwise available to man. The particular ability of animals to feed on foods that are not edible for man is then little used in some countries. In the Model, animals will be assumed to feed only from grazing (non-arable) land and from the portion of agricultural production that is not human food.

International data for inputs and factors identified for livestock production are very scarce, because many of them are not differentiated from those for the agricultural sector. Also, the proportion of livestock production to the total caloric or protein food production is very low (Table 4) and it is likely to remain low in the time horizon considered in the Model. Therefore, it was decided to treat livestock production in a much simpler way than agricultural production.

Table 4. Absolute and relative contributions of world agriculture, livestock and fishery production to total food production in 1970.

	10^9 Kcal.	%	10^3 Tons proteins	%
Agriculture	5,007,061	88.9	167,340	79.7
Livestock	553,611	9.8	28,841	13.7
Fishery	69,596	1.2	13,919	6.6
Total	5,630,268	100.	210,100	100

The procedure was to calculate a global cost of animal production increase, and assume that livestock production will increase linearly as far as economic resources are available, up to a limit set by natural and agricultural constraints.

The oost estimations were obtained from FAO's proposals [4] for animal production increase in underdeveloped regions, for the period 1962-1985. The proposed production increase, presented as meat, milk and eggs, was transformed into calories and proteins, taking into account the proposed relative composition of meat (beef, pork, poultry).

FAO [4] gives estimations of the capital investment necessary to reach the proposed increases in production.

The increase of animal stocks(mainly beef) represents about 70 percent of the capital investment in the livestock sector. According to the basic assumptions of the Model, this increase should not be considered capital investment, because the animal stock is assumed to be society owned, and its increase, according to FAO, is produced through reproduction not through importation of new stocks.

The agriculture related industries (centers for meat and milk elaboration and feed mills) are not included specificially in the livestock sector, and are included in the Economic Sector of the Model.

According to FAO [4] most of the necessary investments in agrarian development are part of an integrated investment input, inherent in the amelioration of cereal production, and cannot be specifically identified with the livestock sector. This investment should not be considered in the livestock sector of the Model. However, it was decided to adopt a pessimistic hypothesis here, by including this cost.

Estimations of capital investment cost of animal production increase, per calory and protein, for the different regions were made. Those costs, per unit increase of animal production, are assumed constant for each block in the time horizon of the model. This is probably a safe assumption, because FAO's estimations were made for regional proposals, assuming little change in the social and economic conditions of the regions. It is to be expected that, under the assumptions of the Model which propose important changes in the functioning of societies, the costs should be lower than those estimated by FAO.

The rate of increase in animal production is then a function of the available capital and of the costs of production increment.

The capital investment for animal production increase is an input from the Economic Sector of the Model. This input ceases when the animal production reaches its maximum value.

The total production of a given year is given by the last year production plus the increase in production.

The Maximal Animal Production

The maximal animal production in a given year depends in the Model on two sources: the carrying capacity of grazing lands, a parameter considered as fixed in the model; and the production of agricultural subproducts, non-edible for humans.

The food production from the livestock and terrestrial animal production is affected by a processing, storage, and distribution loss. This loss is treated in the same manner as the agricultural post-harvest loss, being fixed for developed countries and gradually diminishing (in twenty years) for developing countries, down to the current assumed loss for developed countries.

FISHERY PRODUCTION

The fishery sector of the Model refers to marine animals. The nominal catches (marine and fresh-water fishes) in 1970 (live weight) were calculated from [65].

The procedure followed for modelling this sector was essentially the same as for livestock production. The identified investments proposed for fishery by FAO [4] for each block, were divided by the caloric content of the proposed catch increase in calories. This provides a rough estimation of the unit cost of fishery production increase for each region. This estimate, as that for livestock production, is probably an overestimation of the costs, because FAO assumes the persistence of social and economic conditions. Fishery production, then, is assumed to increase as a function of available economic resources and unit cost of increase.

The capital investment for animal production increase is an input from the Economic Sector of the Model. This input ceases when the fishery production reaches its maximum value.

According to Ricker [66] about two tons out of 12 tons of usable protein are lost in processing and conversion. This represents a loss of 17 percent of usable protein. This value was accepted as an estimate of fishery food loss, and it was considered fixed for all regions.

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Latin American World Model: Theoretical Structure and Economic Sector

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In this paper we present the theoretical structure on which the Latin American World Model has been constructed. This dynamic multisectoral model contains features which are new to the economic literature of its type: the optimization process reflects a social welfare choice based on the requirement that every member of society reaches an acceptable level of consumption of basic necessary goods. Moreover, the dynamic maximization process requires the minimization of the time horizon required to attain those minimum basic consumption levels. These economic choices are based on the assumption of some restricted rationality on the part of the society for the use of scarce resources and on a dynamic system of population growth that exhibits feedback elements from within the system in a submodel which contains empirically tested functions of demographic growth dependent on the economic variables of the system. The economic productive system, in turn, feeds into the growth of its population, and its dynamics is, in part, rationally adjusted to maximize in each sector the production of goods by the selection of alternative technologies.

The Model presents a new approach to structuring global predictive political-economic models presently in use; some rationality is assumed in the system which takes the form of constrained decision control variables. The main assumption we make is that all human-social systems exhibit some degree of dynamic adjustment to the environment. Therefore, simulation models which do not incorporate into their structure some capacity for dynamic adjustment to environmental conditions cannot reproduce, at a reasonable predictive level, a significant part of human political economic systems. This eliminates from our approach simulation models based on intrinsically "projective" structures, even where complex combinations of projections are simulated for each of the variables. Part of the purpose of the simulation model used

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[1]The author has developed this model while working for Fundación Bariloche at Buenos Aires and Rio Negro, Argentina.

here for approximating the optimal solutions is to reproduce these mechanisms of adjustment as they appear in the recent historical data and to simulate their effect in future periods.

A part of the constrained optimization process chooses an optimal distribution of the available capital and labor, and technological coefficients of capital-labor intensities for each of the production functions of the five basic sectors: food production, housing, education, other services and consumption goods complementary to the production of the first three sectors and capital goods. The constraints on the choices of the optimal values of these economic variables are restrictive, accounting for the high degree of inertia and friction that characterizes economic systems at these levels of macro aggregation. The price system enters into this constrained optimization process as an important parameter; however, the minimum requirements of consumption of the basic goods and services are not expressed in monetary value. The dynamic constrained optimization process aims to steer the model along a path of the manifold given by the constraints; which minimizes the time period in which the minimum levels of per capita production of the basic goods are attained. The introduction of an interdependent demographic submodel of population feeds dynamically from the values of the economic variables; in turn, it feeds the labor force parameter used by the economic constrained optimization problem in the choice of alternative technologies to be used in the five different sectors. The production functions of each sector reflect the added productivity of the economically active population as the levels of food consumption, housing, education and health of the population increase.

To prove the existence and basic stability of optimal solutions to the problem, we make use of techniques of calculus on manifolds, differential geometry techniques for calculus of variations, and some specialized results of global analysis for the generic existence of the solutions.

In Section 1 we discuss the model and its dynamics. In Section 2 we present the main mathematical economic results.

THE MODEL AND ITS DYNAMICS

In this section we develop the structure of the economic model and its optimization. Here we present the continuous time, infinite horizon case; other special cases of the model are discussed in the next sections.

The economies of each block of countries[2] have four basic

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[2]For a discussion of the classification of a country inside a block, see Remarks 2 and 4 at the end of this section.

productive sectors which produce the "basic" consumption goods and services of the population, and one investment goods sector:

Sector 1: Food products

Sector 2: Housing

Sector 3: Education

Sector 4: Other consumption goods and services (complementary to the production of sectors 1, 2 and 3 and their consumption)

Sector 5: Capital goods

In the following, $s_j(t)$ denotes the amount of physical goods produced by sector $j(j = 1,\ldots,3)$ at period t (calories, houses, and number of children that can be educated, respectively); and $p_j(t)$ are the prices of each of these units at period t. By the usual assumptions of boundedness of consumption streams, $s = \{s_j(t)\}_{j,t} \in L_\infty^{3+}$, the positive cone of L_∞^3, and we can assume that $p = \{p_j(t)\}_{j,t} \in L_1^{3+}$, the positive cone of L_1^3. $p.s \in R^+$ is the value of the infinite horizon plan s (in U.S. dollars, 1960). $p\cdot_j s_j$ $j=1,\ldots,3$ indicates the total sum of money spent by each of the first three sectors. $p_j(t)s_j(t)$, $j=1,\ldots,3$, $t=0,1,\ldots$, is the value of the consumption of goods j at period t; for instance, $p_1(t)s_1(t)$ is the value of all calories consumed at period t. Note that because of the economic nature of sectors 4 and 5, there is nothing from the physical veiwpoint equivalent to the definitions of s_j, for $j < 3$, for sectors 4 and 5. Hence, by definitions:

$$GNP(t) = \sum_j p_j(t)\cdot s_j(t) \tag{1}$$

Let $p_5(t)\cdot s = k(t)$ and let $k_1(t)\ldots k_5(t)$ be the capital inputs assigned to each sector at instant t; and similarly let $\ell 1(t), \ldots, \ell_5(t)$ be the labor inputs. Note that by definition $k(t) = \sum_j k_j(t)$. Production functions of the Cobb-Douglas type are assumed for each sectors, that is,

$$\rho_j(t)s_j(t) = f_j^t(k_j(t),\ell_j(t)) = (k_j(t))^{\beta_t}(\ell_j(t))^{\alpha_t},$$
$$\text{for } j = 1,\ldots,5 \tag{2}$$

where for all t, $\beta_t + \alpha_t = 1$, so that

$$GNP(t) = \sum_j f_j^t(k_j(t), \ell_j(t)).$$

These forms of the production functions are useful for allowing some flexibility in the optimal capital-labor ratio to be used in each sector; more general production functions can be used at this stage of the model yielding basically the same results we obtain for these types of production functions. In the process of fitting the model to the aggregated international economic data for simulation purposes, see also Remarks 1 and 4 at the end of this chapter. We found these types of functions very useful. Note that f_j^t depends on time; i.e., the model admits a technology which can possibly change continuously over time. In the following we shall restrict the model to the case where $f_j^t = f_j^o$ for all t. The case where f_j^t is not constant is examined in Section 3, as well as the case where the production functions $f_j^{t_o}$ depend on the value of $s_j(t)$, for $t<t_o$, indicating that at different levels of health, education and consumption of basic necessary goods, there are correspondingly different productivities of the economically active population.

The productivity of the economically active population actually depends on the previous history of aggregate consumption of the basic goods: food, housing, education, health, etc. In other words, present consumption of these goods represents a "human investment" that increases future productivity, similarly to present capital investment. In mathematical terms, the production function at time t, f_j^t, is in fact dependent on a parameter $s(\xi) = s_1(\xi)\dots s_5(\xi)$ for $0 \leqslant \xi < t$. Equation (6) in this case defines an infinite dimensional dynamic system -- see for instance [6] and [2], p. 129. Since the parameter $s(\xi)$ belongs to a Banach space of paths, the general proposition that a man's attitude toward his present economic circumstances is conditioned, inter alia, by past experience has also been studied by H.E. Ryder, Jr. and G.M. Heal in [7]. Functional differential equations are a model for a system in which the future behavior of the system is not necessarily uniquely determined by the present, but may also depend upon some of the past behavior. An example is retarded functional differential equations or RFDE. For details, see [2].

Let $t_o = 1960$. We define

$$\frac{k_j(0)}{\ell_j(0)} = ck\ell_j \quad \text{for } j = 1,\ldots,5. \tag{3}$$

The $ch\ell_j$'s are the proportions of capital to labor inputs in 1960 for each sector, in a given block of countries. Let

$$p = p_1(0) + p_2(0) + p_3(0) \tag{4}$$

We now impose the following normalization conditions on the prices of s_j, for $j \leqslant 3$: Assume $p_j \in C^1[0,\infty)$,[2] for all j, and that $p = p_1(t)+\ldots+p_3(t)$, for all t.

Further, assume:

$$||p_j(t)|| \leqslant C \tag{5}$$

for $j = 1,\ldots,5$ and for every t, where $|| \cdot ||$ is the sup norm on $C_b^1[0,\infty)$,[3] and C is a parameter which can be varied in the optimization process within certain limits. Note that here we made a distinction between p_1, p_2 and p_3, and p_4, p_5, because of the lack of concept of unit of physical or real output in sectors 4 and 5. For practical purposes, in the simulation model, p_4s_4 appears as proportional to other sector expenses (approximately 50 percent), that is:

$$p_4s_4 \cong \frac{1}{2}\sum p_is_i$$

This has been done mainly because the data strongly suggest this proportion is a stable parameter through time for all the blocks of countries under consideration.

Note that by condition (5), the normalized prices we use in the model for $t > t_o$ are in general different from the original

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[3] C^1 is the space of continuously differentiable functions on $(0,\infty)$, and C_b^1 the subspace of <u>bounded</u> functions in C^1. Note that, for each j, since $p_j \in L_1(0,\infty)$, if p_j is C^1, then $p_j \in C^1(0,\infty)$.

ones. From now on, define

$$\overline{GNP} = \sum p_j(t)s_j(t),$$

for normalized p_j. Note that in general $\overline{GNP} \neq GNP$.

Different proportions of the $\overline{GNP}$ are allocated for reinvestment in the economy through time. This proportion is denoted by T(t). Therefore,

$$\overline{GNP}(t) = I(t) + c(t)$$

where

$$c(t) = \sum_{j<5} p_j(t)s_j(t)$$

and where by definition I(t) is the gross investment at period t,

$$I(t) = T(t)\overline{GNP}$$

the path of the total available capital at time t, k(t), satisfies

$$\dot{k}(t) + c(t) = \sum_j f_j(k_j(t), \ell_j(t)) - \sum_j \delta_j(t)k_j(t) \quad (6)$$

where $\delta_j(t)$ is the depreciation rate of capital in sector j at period t.

$$I(t) = \dot{k}(t) + \sum_j \delta_j(t)k_j(t)$$

Note that $T(t) = I(t)$ if $\overline{GNP} = 1$, and $T(t) = \dot{k}(t)$ if $\overline{GNP} = 1$ and $\delta_j = 0 \forall_j$. In the case that the variable t takes discrete values (discrete time model), (5) and (6) become, respectively, (5') and (6'):

$$||p_j(t+1) - p_j(t)|| \leq C \text{ for } j = 1,\ldots,5 \text{ and all} \quad (5')$$

$$k(t+1) = k(t) + I(t) - \sum_j \delta_j(t)k_j(t) \quad (6')$$

Recall that by definition, for all t:

$$k(t) = \sum_j k_j(t)$$

Similarly,

$$\ell(t) = [\sum_j \ell_j(t)]e(t,\phi(s_j(\xi))), \text{ for } \xi \in [0,t), \ j = 1,2,3.$$

where $e(t,\cdot)$, $1 > e > 0$,[4] is the proportion of the total population which is economically active at time t, which in general is a function of the level of aggregate food consumption, housing and education at previous periods.

At this point the economic model connects with the demographic submodel: the total feasible labor input at time t, $\ell(t)$, comes from the pyramid of population (see Remarks 4 and 6 at the end of this section). Note that $\ell(t)$ is in turn determined by the values of $s_1 \ldots s_3$ up to period t, i.e., the total $\ell(t)$ is a complex function of aggregate food consumption, housing, education and health at previous periods ξ, $\xi < t$. This function is obtained from adjustments to real data (see Remarks 4 and 6 at the end of this section); the fitting and simulation of future population growth are contained in the Population Sector of this model.[5]

The technological substitution between capital and labor, which is possible given the form of the production functions, is controlled by the following conditions:

$$\frac{k_j(t)}{\ell_j(t)} - ck\ell_j \leqslant ck\ell_j - y_j \quad \text{for all } j \text{ and } t, \tag{7}$$

where $ck\ell_j$ is defined as in (3). Empirically, we determined the values:

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[4]Real values for e in 1960 are: Europe = 0.446, Africa = 0.387, Latin America = 0.429, Asia = 0.433.

[5]See H. Scolnik and L. Talavera "The Functioning of the Model and the Demographic Model."

$y_1 = 0.1$

$y_2 = 0.05$

$y_3 = 0.05$

$y_4 = 0.1$

$y_5 = 0.1$

as feasible values for technological purposes. Conditions (7) reflect the incapacity of the economy to adjust in the short run to optimal capital-labor ratios without large losses of productivity, due to the short-run inflexibility given by fixed capital stock, technology and know-how, and local market and international trade conditions.

To obtain an acceptable optimal policy, from the socio-economic point of view, the following additional constraints are required from the model:

For all j,

$$\frac{s_j(t)}{\ell(t)} \tag{8}$$

are monotone non-decreasing functions of time.

Furthermore, some boundary constraints for the real value of the variables are assumed:

$$\frac{s_j(t)}{\ell(t)} \leqslant c_j \quad \text{for } j = 1,2,3 \tag{9}$$

The task of the optimization process is to minimize the time required to attain minimum values of the basic variables $\frac{s_1}{\ell},\ldots,\frac{s_5}{\ell}$, i.e., to find a feasible path satisfying the requirements of the model: (2), (4), (5), (6), (7), (8) and (9), and initial conditions (3), and also for all j the following initial conditions:[6]

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[6]The right-hand side values are those of 1960.

$$\ell_j(0) = \ell_{jo}$$

$$p_j(0) = p_{jo}$$

$$s_j(0) = s_{j0}$$

$$k_j(0) = k_{jo}$$

$$k_j(0) = I_{jo}$$

<u>Dynamics of the Model</u>

The task of the model is to find an <u>optimal</u> path of allocation of capital and consumption in the basic sectors of the model, $k_j^*(t)$, $s_j^*(t)$, $j = 1,\ldots,5$, satisfying all restrictions of the model (2) to (9). Along this optimal path the system attains required levels $\{s_j^o\}_{j=1,\ldots,4}$ of per capita consumption of basic goods in the minimum time. Thus, if $\tilde{k}_j(t)$, $\tilde{s}_j(t)$, $j=1,\ldots,5$ is another admissible path satisfying all the constraints of the model (2) to (9), then if

$$\frac{\tilde{s}_j(t_o)}{\tilde{\ell}\ (t_o)} \geq s_j^o \text{ , for all } j,$$

then

$$\frac{s_j^*(t_o)}{\ell^*(t_o)} \geq s_j^o \text{ , for all } j,$$

i.e., $\tilde{k}_j(t)$, $\tilde{s}_j(t)$ reaches the required levels not before $k_j^*(t)$, $s_j^*(t)$. The model proceeds dynamically as follows: at each time an allocation is made of all resources and factors of production among the sector which produces capital goods for saving or investment purposes for future production, and the consumption sectors $s_1 \ldots s_4$. The "control" variables are $\{k_j, \ell_j\}$, as defined above. Total capital available at t is given by equation (6), and in the discrete time case by equation (6'). The total labor available is a complex function of the education, housing, food production and health levels of the previous periods. The levels of these variables also affect the productivity of the population, which is reflected in the dependence of the production functions of these levels in the previous periods. The optimization process determines the optimal path, which reaches the required levels in a minimum of time with respect to all admissible paths.

In the following section we shall present the theorems that yield the generic existence of a solution to the system.

Remarks

1. Cobb-Douglas' functions were selected in part to allow the possibility of substitution between factors of production, a most important point for the treatment of developing countries. It was also decided that there is constant returns to scale, principally due to some undesirable implications of continually increasing or decreasing returns in long-term models. For the same reason, the explicit consideration of the coefficient that measures technological progress has been discarded, at least in this first stage.

2. For the purposes of the model, the world was divided into blocks, in accordance with the following criteria:

- There is a small group of scattered countries with economic and social indexes comparable or superior to those of Europe. This group is formed by the USA; the USSR, Japan, Australia, New Zealand and Canada.

- Economic and social indicators of Latin-American and Caribbean countries clearly place them in an intermediate situation with regard to Europe and Africa.

- Most countries of Asia and Oceania have economic and social indicators intermediate between Latin America and Africa. They cover a wider spectrum, but compared with these groups, their outstanding feature is a relatively higher density of population.

Accordingly, four blocks were defined: one of developed countries and three of developing countries. The first one is formed by Europe, including in this case Israel and Lebanon; the USA, the USSR, Japan, Australia, Canada and New Zealand. The remaining three are: Latin America and the Caribbean; Asia, which includes Turkey and excludes the USSR; and Africa. Those countries with a population under one million in 1960 were excluded.

3. The economic international relations are not considered explicitly in the present version of the model. The main

reason is the intrinsic difficulty of its treatment; however, a few remarks on this point are necessary. International commerce of the four blocks can be considered at equilibrium, except in the case of a defined flow of transference of capital between blocks. The explicit treatment of transference of capital between blocks has been contemplated in the formal structure of the model; obviously it would manifest as a difference between saving and investment -- negative for the donor, and positive for the receiver.

The model does not exhibit the form that the international interchange at equilibrium actually has. Variations in the terms of interchange and of service of factors have not been explicitly defined. However, unless the evolution of the terms of interchange and of the service of factors can be defined in functional terms upon variables observed in the model (which is certainly impossible), their temporal evolution will be externally determined and, consequently, there is no reason to treat them differently than the flows of capital.

4. The data bank of the model was built using essentially compilations of specialized agencies of the United Nations in particular the yearbooks on demography, statistics and national accounts, and information from, OIT, UNESCO, and FAO.

Despite the great amount of information compiled, it has to be recognized that the present availability of data is far from satisfactory. As a result, some degree of subjective judgment is unavoidable in the process of selecting data and in covering gaps of information. Tests will be made with the model to verify its sensitivity to variation on the data used.

5. The global dynamics of the model is suggested graphically in Figure 1. The initial data on active population, activity rates, and stock of capital determine in each period the production levels of the five sectors of the model. Actual data are used for $t=0$ period; the values for $t > 0$ arise from the combination of the initial conditions and of the constrained optimization process. The sectorial composition of the production determines the structure of the occupational sector.

The level of physical production of food, housing and teaching services, divided by the population, determines the levels of satisfaction of basic needs.

Given the initial situation, the yearly housing investment determines the urbanization rate, as it is assumed that all inversions in this sector are assigned to urban type housing.[7]

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[7]See D. Mossovich, "Urbanization and Housing."

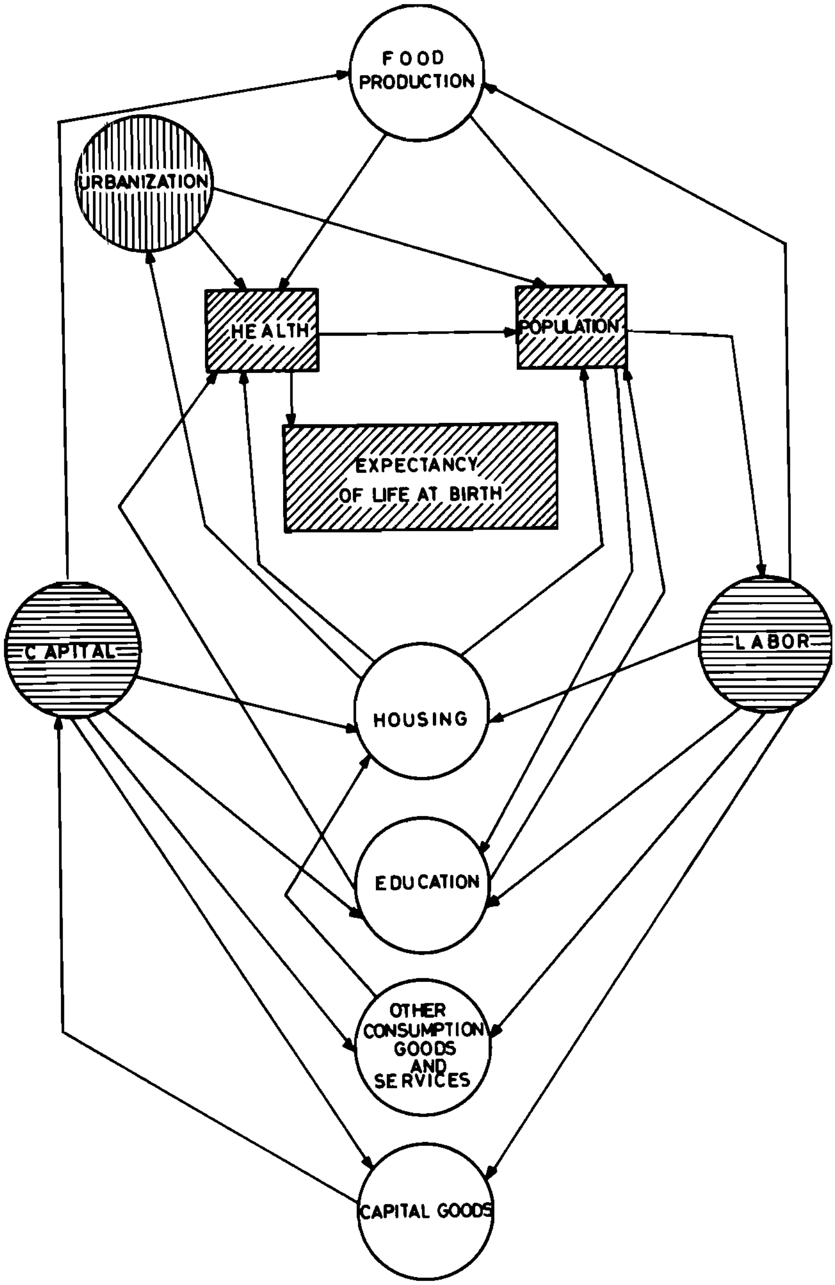
FOOD PRODUCTION
URBANIZATION
HEALTH
POPULATION
EXPECTANCY OF LIFE AT BIRTH
CAPITAL
LABOR
HOUSING
EDUCATION
OTHER CONSUMPTION GOODS AND SERVICES
CAPITAL GOODS

Figure 1.

The main demographic variables, such as birth and death rates and expectancy of life at birth, are determined by the socio-economic variables.[8]

The connection between two periods takes place through gross investment (capital goods sector) adjusted by depreciation, and by population and labor growth rates.

6. The explanation of the evolution of the population, of the life expectancy at birth and of the number of family members, as functions of socio-economic variables, conforms to the purpose of this sector of the model. The main difference between this demographic model and those generally in use is that it is not a projective model; in other words, it does not extrapolate observed tendencies, but it explains them as dependent variables of socio-economic phenomena.

A large number of tests were carried out until the functional relations connecting the variables with respect to their positive and negative influence were in agreement with our empirical knowledge of them (see demographic sector).

GENERIC EXISTENCE OF SOLUTIONS

In this section we prove the existence of solutions to the systems presented in Section 1 for most economies. An economy in this context is defined by the following parameters: initial data on capital stock, population, production functions and output of the five basic sectors, investment, and limitation of availability of natural resources. The space of all economies ξ is then the product of the spaces P_i, of which these parameters are elements. In this case, since some parameters are functions, some of these spaces P_i are Banach spaces of functions. So ξ inherits naturally a Banach space structure. "Most economies," in this context, means an open and dense set in ξ , with respect to the topology just described.

Let $M \subset R^{10}$ be the bounded region of possible values of $\{k_j\}$ and $\{\ell_j\}$, for $j = 1,\ldots,5$ and all time + (boundedness is given by initial economic conditions and boundedness of resources available).

Let P(M) denote the space of C^2 paths of M. (Recall that a C^2 path is a C^2 map of some interval $[t_o,t_1)$ of real numbers into M.) P(M) has a natural infinite dimensional manifold structure (see [3] and [5]).

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[8]See H. Scolnik and L. Talavera "The Functioning of the Model and the Demographic Model."

Definition

A subset π of P(M) is a path system if it has the property that if a path $o \in \pi$, all paths obtained from o by changing the parameterization and by restriction of o to a subinterval of $[t_o, t_1]$ also belong to π.

Definition

For $p \in M$, let the accessibility set of p denoted $\pi(p)$ be the set of points in M than can be joined to p by a path in the system π. Let H_p be the subspace of TM_p, the tangent space of M at p generated by the equations:

$$k(t) + c(t) = \sum p_j f_j(k_j(t), \ell_j(t)) - \sum \delta_j(t) k_j(t) \tag{1}$$

where

$$k(t) = \sum_j K_j(t) \qquad \text{for all } t, \quad k)0) = k_{t_o}$$

and

$$s_j(t) = f_j^{\,t}(k_j(t), \ell_j(t), s_j(\xi)) \quad \text{for } \xi<t$$

$$c(t) = \sum p_j(t) s_j(t)$$

and for all t, j = 1,...,5:

$$\ell(t) = \varphi(\ell(t), k_j(\xi), \ell_j(\xi), f_j^{\,\xi}) \quad \text{for } \xi<t \tag{2}$$

$$\sum \ell_j(t) = \ell(t)$$

$$\ell(0) = \ell_{t_0}$$

$$F\ell(t) = \phi(\ell(t), K_j(\xi), \ell_j(\xi), f_j^{\,\xi})$$

$$F\ell(0) = F_{t_o}$$

where $\ell(t)$ is the population and $F\ell$ are the family units at time t. φ and ϕ are (empirically adjusted) demographic growth functions in continuous terms. Note that $\ell(t)$ depends, as seen in Section 1, on the total level of past consumption of the basic goods up to period t.

Further, the following "friction" constraints are required, as in Section 1:

For all $t \in [t_o, t_1]$,

$$||p(t)|| \quad c \tag{3}$$

$$\frac{k_j(t)}{\ell_j(t)} - ck\ell_j \quad \leqslant ck\ell_j - y_j \tag{4}$$

where

$$ck\ell_j = \frac{k_j(0)}{\ell_j(0)}$$

and

$$s_j(t) = f_j^{\,t}(k, \ell, \cdot) \tag{5}$$

is C^2 monotonous non-decreasing on t, homogeneous of degree 1 in (k, ℓ) and C^2, monotonously non-decreasing as a function of the paths $k_j(\xi), \ell_j(\xi), f_j^{\,\xi}$, for $\xi \in [t_o, t]$, $t \leqslant t_1$. This last condition indicates the dependence of the productivity of the economically active population on previous levels of "human investment" or previous consumption of the basic goods: food, housing, education, health, etc.

Assume furthermore:

$$\frac{s_1(t)}{\ell(t)} \leqslant c_1, \quad \frac{s_2(t)}{F\ell(t)} \leqslant c_2, \quad \frac{s_3(t)}{\ell_b(t)} \leqslant c_3 \tag{6}$$

where $\ell_b(t)$ is the subset of the population of individuals aged b years or less at time t, which is the part of the population which mostly consumes s_3.[9]

Let $H = \{H_p\}_{p \in M}$ be the corresponding real subspace of $V(M)$, the space of all C^2 vector fields on M.

Let $\pi(H)$ be the following path system on M, defined by H:

A path $o(t)$, $t_o \leqslant t \leqslant t_1$, is in $\pi(H)$ if and only if $o'(t) \in H_{o(t)}$ for $t_o \leqslant t \leqslant t_1$.

Definition

A vector field system H is completely integrable if and only if $[H,H] \subset H$. ($[A,B]$ is the Jacobi bracket of the vector fields A and B.)

We now state without proof the following result, which is an application of the implicit function theorem (see [4]) and transversality theory (see [1]):

Lemma 1. For an open and dense set of economies in ξ, the set $M \subset R^{10}$ given by the constraints (1) to (6) is a manifold.

Let π be the accessibility map defined at the beginning of this section.

Theorem 1. For most economiex $\pi(p) = M$, for all $p \in M$.

Proof. By Chou's accessibility theorem (cf. Theorem 18.1 of [3]), since M is a manifold for most economies in ξ, it is enough to prove that $D(H)$, the smallest completely integrable vector field system on M containing H, satisfies

$$D(H) = V(M) \quad .$$

This condition can be checked directly by performing straightforward computations on equations (1) to (6) which define H. Note that (1) is actually a family of equations indexed by the set of feasible consumption paths $\{c(t)\}$. Recall that given the price parameter p, the $c(t)$ are defined in (1) as functions of the $s_i(t)$, which are monotonous non-decreasing functions by assumption (5).

Corollary. The minimum required levels $s_1^o, \ldots, s_5^o$ are

[9]See G. Romero Brest, "Education Model."

accessible through paths in the system H, for all initial values of k_{j_o} and ℓ_{j_o}, j = 1,...,5. (That is, there exist paths $\{k_j(t), \ell_j(t)\}$ such that for some $\xi \in [0,\infty]$ the corresponding $s_j(t)$ satisfy:

$$\frac{s_j(\xi)}{\ell_j(\xi)} \geq s_j^o, \quad \text{for } j = 1,3,4,5$$

and

$$\frac{s_2(\xi)}{F_{\ell 2}(\xi)} \geq s_2^o . \quad)$$

<u>Proof</u>. This follows immediately from Theorem 1 and the fact that the values $s_1^o, \ldots, s_5^o$ are contained in the range of the f_j^t for large enough values of the variables on their domain.

We now assume:

$$\text{a)} \quad ||k_j|| \leq N, \quad j = 1,\ldots,5 \tag{7}$$

$$\text{b)} \quad ||\ell|| \leq M$$

Assumptions (7) represent constraints on the capital absorption capacity of the economy, and on the growth of the population in the foreseeable future (i.e., $t \leq t_1$).

<u>Theorem 2</u>: <u>There exists, generically, an optimal solution, i.e., a path in $\pi(H)$, for the system, which attains the required values s_j^o, j=1,...,5 in a minimum of time</u>.

<u>Proof</u>. By (7) the set of feasible paths $\pi(H)$ is compact in the C^1 norm (since it is C^2 bounded and the paths $k_j(t)$ and $\ell j(t)$ are C^2). The map $\ell : \pi(H) \to R^+$, defined by $\ell(o)$ = length of o, is a continuous map on the space of C^2 paths of M, with respect to the C^2 norm.

To each C^2 path $(k_j(t), \ell_j(t))$ the associated output $s_j(t)$

defines a map:

$$M:\pi(H)\to P(R^5),$$

$$M(o(t)) = \{S_j(t)\}$$

M is continuous with respect to the C^2 norm by definition, since the production functions f_j^t are C^2.

Define the map $L:\pi(H)\to R^+$ defined by the composition:

$$L:\pi(H)\to R^+$$

$$L(o(t)) = \ell \circ M(o(t))$$

L is continuous, since ℓ and M are continuous; thus L attains its minimum at $o^*(t) \in \pi(H)$. By definition of M, $M(o^*)$ is an optimal solution for the system.

Note that the solution of Theorem 2 may not be unique. It is therefore possible to obtain a set of optimal growth paths for the economy; policy considerations may determine the most desirable paths within the set.

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Discussion

Wolfgang Blaas, Rapporteur

Ghabbour opened discussion of the Food Model by saying that aerable land can not be enlarged, and the use of fertilizers and pesticides can have negative side effects, for example, on fish production and erosion.

Soil should not be discussed negatively; one should differentiate between different types of soil which have different production characteristics.

It would be interesting to know whether there are significant relationships between soil yields and the use of pesticides.

Replying to the last statement Gallopin said that no relationship has been found; however, there are not sufficient data available. On the problem of soil identification, Gallopin stated that there is too little (or no) estimate available. He believed that the problem of the negative side effects would be satisfactorily solved.

Aubauer stated that food production can be viewed only in connection with the entire eco-system. Thus, the food-subsystem should become a stronger part of the entire ecological condition.

He also stated that since the use of artificial means in agricultural production is extremely costly, this can create major financial problems for undeveloped countries. Also, fish production can not be enlarged in an unlimited manner, since here there is also an equilibrium boundary.

Gallopin replied that the model considers the eco-system. In the model, fish production can increase within the stated (linear) boundaries of economic activities set by the United Nations Food and Agriculture Organization (FAO). As regards the high (cash) cost of the various fertilizers and pesticides, Gallopin stated that these costs include the establishment of indigenous industries for producing these items.

Roberts inquired about the stipulations of meat production (cattle raising), and also if the energy costs of food production have been considered. Gallopin answered that meat production is integrated as a by-product of farming in the agricultural sector, where it is estimated that 15 percent of the non-farmed land is used for grazing. Costs derived from energy consumption in food production are only indirectly included in the model under the energy sector.

Kaya noted that for Asia in particular irrigation technology is important, and asked if irrigation costs are integrated into the model. Gallopin answered that the irrigation costs are integrated under the title "land development costs."

Brolsma asked about the production function in the field of agriculture. If this does not exist, can farm yields be estimated? Gallopin replied that a production function does indeed exist.

Rademaker noted that there can be no correlation between the use of pesticides and the size of agricultural yield, because the use of pesticides is only of a corrective nature with repsect to the development of food production.

McPherson asked the meaning of the expression "maximal food production", to which Gallopin replied that it is the maximum agricultural yield of a uniform area. Gallopin noted that a certain balance exists between the allocation for fertilizers and pesticides, and for "land development."

Discussion then took place on the "Economic Sector and the Global Theoretical Structuring of the Model". The meeting focused attention on a few technical questions, for example, work integration of functions. In McPherson's opinion there was some confusion in the paper about which size(s) is (are) optimized. Koopmans, addressing himself at this point, explained that certain "minimal standards" are to be reached to satisfy the basic requirements in the space of minimum time.

Horvath inquired about the role of capital in the model. He noted that capital is aggregated in the model in the manner used for macroeconomic models, and asked whether this innovative model does not want to open new areas that could be regarded as capital-differential. Chichilnsky replied that the United Nations' data are too crude for a differential treatment of capital. Koopmans added that the disaggregated treatment of capital would certainly be desirable, but one would then have to consider an extremely high cost of data production and manipulation.

Informal Discussion (Evening Session)

Ferenc Rabar, Rapporteur

Rademaker opened the session, stressing its informal nature. He asked for tolerance and openness in the discussion. In his opinion, the meeting was a good opportunity to explore the essentials of the model. He proposed the following framework for discussion.

The nature of the model as it stands:

- Overall structure;
- The role optimization plays in the model step-by-step optimization, and overall optimization through time;
- What happens in the model as a function of simulated time;
- Technicalities;
- The model's behavior.

The future of the model:

- What the team would like to add to the model;
- What others suggest adding to it.

Rademaker asked for comments on his proposed framework.

A number of suggestions were made by the participants.

Jarett said the assumptions that have been made in each of the segments should be discussed. Roberts, referring to Rademaker's analogy, said that this model is a "riverbed" model in which the constraints are like cliffs and have an important role. He wanted to discuss the sensitivity of these constraints. Katz wanted a discussion of time delays. Curnow suggested finding simple words, almost analogues, for what was being done. McPherson and Koopmans suggested that the questions raised by the audience during the presentations be treated.

Rademaker summarized the opening remarks and suggested incorporating them in the framework he had proposed. As discussion time was limited, only the nature of the model as it stands would be treated. He first presented his view of the basic relationships of the model with the following graph:

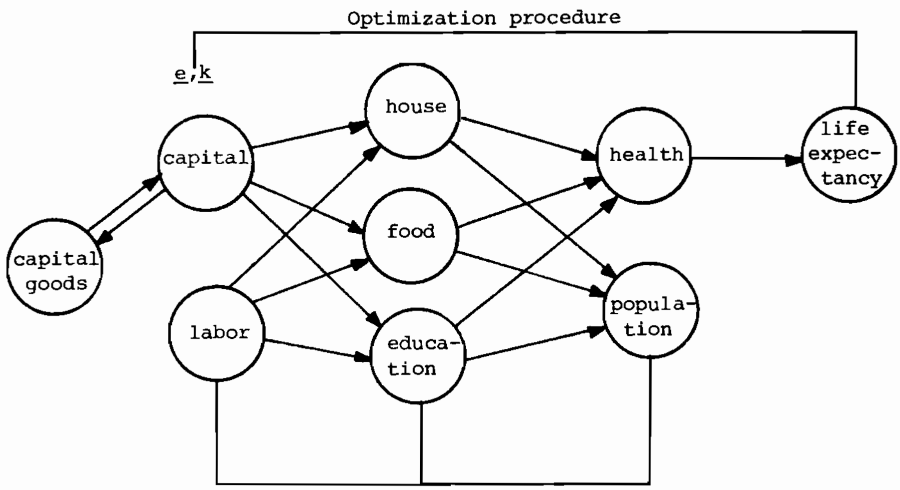

Figure 1

Here the major control is exercised through capital (k) and labor (1) allocation. After this is determined, secondary calculations follow.

Koopmans, referring to the time constraint of the meeting, stated that there should be no restatements of previous comments about food, housing, education etc..

Curnow suggested that the final report include a list of all the inputs and outputs of all subsystems rather then hold a discussion of them at the meeting.

Ghabbour said that housing, health, and food also have a great influence on education, which is not reflected in the model. McPherson asked what was meant by the model adopting and learning. Scolnik answered this question by saying that since the model does not change its structure, it is not a learning system in the true sense of the word.

The two different kinds of optimization mentioned during the presentations were then discussed:

- How to allocate resources to get the maximum life expectancy (LE) in each time period t; and

- How to minimize the time needed to meet the basic requirements of the population.

Curnow said that he expected the process of maximization of LE to lead also to the minimum time of meeting the basic requirements. Scolnik added that the present version of the model includes optimization at every time period. Koopmans stressed that what had been done in the model was a momentary optimization, and that he did not see how this could lead to an optimization through time. Rademaker questioned whether these two kinds of optimization would necessarily give identical results. Bernardini was in favor of optimizing present problems and giving priority to the present rather than the future.

Rabar asked for a clear answer to a question raised earlier by Rademaker: does the model include two different types of optimization procedures within two different objective functions, or is there just one? Scolnik replied that only one was included: that of momentary (annual) optimization. The other had not yet been programed, but had proved to be solvable.

Referring to the point about what changes in the model as a function of the simulated time, McPherson asked how the transition from projection to optimization takes place? Rademaker and Scolnik jointly replied with the following scheme:

1960 start) 1970)	data fit.		
1980) 2000)	correcting housing etc.	→	momentary optimization

The question of time delays was discussed. In reply to Katz's question, Scolnik said that although in real life time delays do exist, the model does not include them. Birth rate and the like are related to variables of the same year.

Chichilnisky commented on the question asked by Roberts at the beginning of the meeting about the sensitivity of constraints. In her opinion constraints were in fact very sensitive, according to the analyses done.

de Julio asked what the model builders would do if it were not possible to reach the target set owing to some constraints. (Relaxing the constraints with the momentary optimization was not possible.) Scolnik replied that an order of preference is included in the weights of the objective function to take care of the problem. McPherson asked whether causes and effects could be identified in the graph presented.

Koopmans asked how aid from developed to underdeveloped regions functions. Scolnik replied that the aid was directly proportional to the population and inversely to the LE of a region.

Rademaker took note of the wish of the Bariloche team to have yet another meeting. He closed the discussion with words of thanks to the participants.

The Education Sector

Gilda Romero Brest

THE PLACE OF EDUCATION IN THE OVERALL MODEL

In the Model education is considered one of the basic needs of men and societies, which for the former is a constant need throughout life. Education is also a factor of fundamental importance in achieving the desired society. The central role of education is clearly outlined by the premises and ideas developed within the socio-political framework of the Model.

The normative character of the Model implies that faced with the dilemma of determinism versus freedom, the choice is freedom, that is, the praxis or the political line of action. The fundamental premise is that reality and history do not develop as "happenings" but rather as the result of human activities, even though the existence and appearance of conditions, restrictions, contingencies and chance are recognized. One also acknowledges the possibility of designing a vast spectrum of viable alternative futures as well as the possibility of programming, carrying out and controlling the collective lines of action which should lead to the chosen future among the possible options.

This future constitutes only one point on the continuum of the history of nations. Men and society do not constitute separate elements of a dichotomy, nor are they entities subject to a value preference with respect to each counterpart. On the contrary, both are perceived as sets of open systems, integrated into an ecosystem-which includes the biological and social dimensions of human life and its habitat- whose functioning and regulation is derived from its dynamic interaction.

The ideas that guide this work lead us to prefer a future in which world society achieves a real social justice among the different regions and countries as well as among the various population groups inside national boundaries. This achievement is thought of as the product of full participation in the decisions and the operation and control of matters of national and social interest. The position adopted also advocates a shift of the value focus from quantitative growth to qualitative expansion, in an attempt to achieve a generalized quality and dignity of individual and collective life.

When men are visualized as agents of their reality and as history makers, education acquires a crucially significant role. As a process dealing with the acquisition of the socially expected behavior, education becomes a tool capable of allowing people to participate in an enlightened and competent manner in the design and construction of the future.

From the social perspective, education may result in strategy of change toward the privileged collective future and, from the individual viewpoint, in the activities and processes needed to achieve, benefit from, and enjoy the quality of life and human dignity positively perceived and valued.

LIFELONG EDUCATION: A FRAMEWORK FOR FUTURE EDUCATION

The desirability of a generalized participation in the permanent design and construction of the future requires that the individual receive a lifelong education. The tasks expected of individual demand the constant acqusition and renewal of resources needed to organize behavior, since all-or most of these resources rapidly become obsolete and lose the power to create and proceed toward unknown situations. The demand for renewal and replacement applies to the various components of the systems of tools for behavior: values, ideas and beliefs; ways of perceiving, thinking and judging; information and knowledge; techniques and skills; attitutes, motivations and interests.

If one accepts that change is not mere happening but in fact the result of social activity, two issues become evident. First, the lifelong education process cannot be viewed as an adaptative response to a given reality; it is not a matter of learning and changing so as to live or survive, but rather a matter of living and learning so as to change and to participate in the processes of generating changes. Moreover, lifelong education is not thought of here as a consequence of but rather as a condition for, steady change in the direction desired. In short, education is a means for allowing men and nations to be self-determining with respect to their destinies. Secondly, if education is conceived as a lifelong process for creating and interacting with new and innovative factors, then traditional education that adjusts the individual to the existing order will have to be substantially reduced. Thus we advocate an education process which allows one to progress from the acceptance of and submission to the established order to the construction of the desired order. This implies developing capabilities to do the following: a) perceiving, becoming aware of and discerning social circumstances, processes and mechanisms that generate unsatisfactory situations of hinder progress towards the society and quality of life chosen by and for the majority; b) transforming criticism and dissent into behavior oriented toward change; and c) building up strength and motivation for the sustained solidary action required to achieve change in unsatisfactory situation.

Thus, the institutionalization of change as something sought after and provoked leads to an institutionalization of education as a lifelong process. This refers to the expected lifelong educational activity of individuals and to society's responsibility for providing and insuring adequate services to all age groups and social sectors, in accord with their varied and changing interests and needs.

The field of education is limited here to deliberate, conscious, and organized learning processes. This boundary in no way means that education is identified with scholarly or formal learning. Our field includes: a) in-school and out-of-school education; b) initial and subsequent educations; c) formal education, corresponding to the different levels and modalities of the school system non-formal education centers on the acquisition of specific skills for the diverse activities of one's personal, domestic, social, economic, political or cultural life, and informal education pursues personal growth and expansion; d) institutionalized and independent education which takes place beyond the institutional facilities, prescription and control; and; e)direct or face-to-face education as well as indirect or distance-mediated education by means of a variety of technological devices.

Adopting the idea of lifelong education as a framework for determining the minimal levels for satisfying educational needs requires that we point out some of the implications for designing educational policies and strategies. First, in-school education of young people constitutes only the initial stage in a process which should continue throughout life in order to satisfy the changing manifestations of an individual. Second, it thus seems reasonable to abandon the scheme of formal education as well as to revert the present trend of extending the duration of compulsory education. Instead, it seems convenient to adopt a scheme which distributes throughout a person's lifespan all education subsequent to the initial basic education.

Third, lifelong education of adults does not mean uninterrupted full-time education but rather part-time education. It means a regular return to the learning process at various stages of life, and during periods that vary in length and with a flexible amount of dedication in terms of time, and an alternation with other activities (work, social or personal tasks and experiences). To claim that education is a lifelong need and process implies that education enters into the set of normal and regular activities which individuals carry out throughout their lives. Fourth, the hope of a long life, interwoven and bound up with a many-sided transformation of reality confronts man with situations of change in all spheres, groups and situations in which they are involved work, politics, community and home life, culture, sports or recreation. Lifelong education is conceived not as a process coextensive with life but also coextensive with the vast and diversified spectrum of man's spheres of activity and of the groups and situations in which he finds himself involved. Education can be extended in time to become impoverished and alienating if it limits itself to training and bringing up to date the qualifications demanded by changes in the productive sector, and even more so, if it is carried out as the only way to keep one's employment. The lifelong education suggested neither creates privileges nor limits one's scope to only some areas of activity to the detriment of the remaining activities or facets of human fulfilment or expansion.

The following will be some of the features of the suggested education process.

a) post school education will cover a larger span than school education; b) non-formal education will expand its domain considerably, and will become the broadest area within the education complex; c) institutionalized (formal and non-formal) education, will be only one of the possible ways of satisfying the needs of post-school education. (To a large extent, this activity will be carried out autonomously, i.e. self-programed and self-controlled); and d) the adult population will have access to a vast and diversified network of educational services, somewhat like a huge "educational supermarket."

In this setting the possibility of generalizing education as a normal and regular activity throughout people's lives and of insuring that all obtain the maximum benefit and satisfaction requires that the total population have the necessary ability and competence to carry out autonomously their own education. This is one of the key points to keep in mind for the type of education envisaged.

To ensure that everybody is equipped with and able to master the required tools to engage in a lifelong education project becomes the main function and responsibility of the first or basic level of schooling. This requires a reconsideration of present standards in order to ensure the fulfilment of the first level of schooling. We propose that the present standards be replaced by the achievement standard which we label "educational take-off point".

The educational take-off point is the achievement of the basic threshold of autonomy, self-reliance and self-sufficiency for efficiently deciding programming and controling one's education as well as that of the groups to which one belongs. To accomplish the level we would need the following: a) to have a constant and self-renewing motivation for learning; b) to have full command of the current languages and techniques of communication; c) to master the learning tools that is, to have "learned to learn" on one's own and in a group, both within and outside the school systems. This involves cognitive and creative capabilities as well as skills to cope with learning materials and situations; d) to have the basic conceptual structures to deal with the various realms of reality, and to be able to handle the systems of categories of the fundamental areas of knowledge, as well as the rules needed to insert into an operative whole new pieces of information; and e) to have attitudes favorable to personal and group autonomy, a positive disposition toward change, the unknown, the unexpected, the unstable and the ambiguous. In addition, to be firm and ready to make decisions, to feel able and willing to invent alternative futures, and to get involved in the task of constructing them.

MINIMAL EDUCATIONAL LEVELS FOR THE DESIRED SOCIETY

For reasons which touch upon the very philosophy of the Model, we will point out only the minimal educational levels that are considered necessary to satisfy the individual and social needs for the world we postulate. The desirable levels fall into the following four categories.

1) Basic initial education of the young population starting at the age of six (98 percent of the age group) and aimed at achieving the educational take-off point. We estimate that this standard could be reached in a period which varies from between 8 and 12 years of schooling (for the runs of the Model, the maximum limit of 12 years was adopted).

2) Secondary and higher education aimed at training a critical mass of middle and higher level human resources. The need for economic, political, and social activity and also for the autonomous and self-sustaining development of science, technology and "culture", demands that part of the population receive secondary and higher training. It is a reasonable goal that at least 7 percent of the total population attains the secondary level and 2 percent reaches the higher level.

3) Continuous education. The whole adult population, between 20 and 50 years old, will receive three years of education (one/tenth of one's active life, which is estimated at 30 years), distributed in thirty modules, each equivalent to six weeks full-time education. This scheme purports that 12.5 percent of the population in that age group will be cared for annually. The availability of continuous education for the adult population seeks to insure opportunities for bringing up to date, reconverting, advancing or extending the previous training or qualifications, be it to satisfy the needs arising from the different spheres of activity, or the desires, aspirations or interests concerning personal fulfilment, expression or expansion.

4) Compensatory education. Until the goal of universal basic education is reached, it will be necessary to provide compensatory educational services for the adult population which, in their early years have failed to achieve the minimal level established

for the young population. This compensatory education aims at having all adults who are educationally handicapped reach the minimal standard proposed for the initial education that is, the educational take-off point.

The quantitative differences between the minimal levels proposed and the present day situation can only be appreciated with relative accuracy with regard to school education for children and youngsters (see Table 1). There is a lack of data at the world level for out-of-school education and for adult education in general with the exception of illiteracy rates.

The UNESCO data shows that the more developed countries have already achieved universal primary education. In the less developed areas one can observe that the enrollment rates at the same level are at a considerable distance from that goal. In Latin America the enrollment reaches 75 percent; in Africa 40 percent; and in Asia 55 percent. To this one must add that the drop-out rates are especially high in several regions (above all in rural areas), so that the indices for Africa and Latin America oscillate between 55 and 60 percent, and in both areas one quarter of those registered in first grade repeat this grade. In both Asia and Africa there is also a marked inequality in the sex distribution of the enrollment (see Table 2).

According to UNESCO, in 1970 about one third of the world's population over 15 was illiterate (74 percent in Africa; 47 percent in Asia, and 24 percent in Latin America). This high rate of illiteracy is sufficiently eloquent to illustrate the gap between the present day situation and the one which is desirable.

QUALITATIVE ASPECTS OF EDUCATION

To establish quantitatively the satisfaction of the minimal educational needs would not only imply a partial answer to the problem, but also one which is contradictory to the basic postulates of the Model. What is being postulated for the society is a significant devaluation of mere quantitative and cumulative growth. In educational terms, this implies that it is not merely a matter of giving more education to more people and for a longer period; although this development is undoubtedly necessary, it is no less true that in its qualitative aspects (type, form, and organization) today's education is unsatisfactory for the ends which are being persued.

In qualitative terms, the main features of the education we are aiming at are explained below.

Prospective Orientation

If the possibility of repeating the past or of extending

Table 1. Average Enrollment Ratios of the Population from 6 to 20 Years of Age, by School Levels, 1966-1969[a].

Region	Ratios	Age Level 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Europe and developed countries	1+2	79.3	97.7	97.7	97.3	96.2	91.1	94.3	89.2	86.6	70.1	52.3	36.6	14.2	6.2	4.0
	1^0	79.3	97.7	97.7	97.3	86.2	78.4	50.9	25.0	14.7	5.9	1.0	0.2	-	-	-
	2^0	-	-	-	-	10.0	12.7	43.4	64.2	71.9	64.2	51.3	36.4	14.2	6.2	4.0
Latin America	1+2	35.7	79.8	90.9	89.4	90.2	83.8	81.0	66.6	47.1	39.7	22.2	17.0	11.5	7.1	1.5
	1^0	35.7	79.8	90.9	89.4	90.1	82.9	71.7	49.3	26.3	10.8	4.1	1.7	0.9	0.4	-
	2^0	-	-	-	-	0.1	0.9	9.3	17.3	20.8	28.9	18.1	15.3	10.6	6.7	1.5
Africa	1+2	25.5	46.2	49.8	48.3	46.9	43.2	39.6	31.2	25.6	19.7	10.7	6.6	4.4	2.4	1.0
	1^0	25.5	46.2	49.8	48.3	46.9	42.8	37.8	27.2	19.3	10.6	4.3	1.1	0.3	-	-
	2^0	-	-	-	-	-	0.3	1.8	3.9	6.3	9.1	6.4	5.5	4.1	2.4	1.0
Asia and Oceania	1+2	50.8	73.9	78.2	75.0	72.1	66.3	57.6	48.6	38.0	30.6	26.5	19.8	13.4	8.0	3.3
	1^0	50.8	73.9	78.2	74.8	63.9	54.2	35.3	27.0	10.5	4.1	1.2	0.1	-	-	-
	2^0	-	-	0.02	0.2	8.2	12.1	22.3	21.6	27.5	26.5	25.3	19.7	13.4	8.0	3.3

a) Data for the U.S.A., the U.S.S.R., and China are not included.
Source: UNESCO Statistical Yearbook, 1971, United Nations, New York.

Table 2. Average Enrollment Ratios at the Primary and Secondary Levels, by Sex, 1970[a].

Region	Elementary Level		Secondary Level	
	% Boys	% Girls	% Boys	% Girls
Europe and Developed countries	51	49	53	47
Latin America	52	48	52	48
Africa	64	36	68	32
Asia and Oceania	63	37	76	24

a) Data for the U.S.A., U.S.S.R. and China are not included

Source: UNESCO, Statistical Yearbook 1971 United Nations.

the present is discarded, and if the option is that of commiting oneself to a sustained and intense transformation of reality, then education functions not as the "guardian of history" but as the insurer and reinforcer of the existing order. Above all, one must seek to implement an education projected into the future, which at all times should try to make people capable of processing the desired future through their present behavior.

Individual and Social Relevance

The main point is that education should be firmly and authentically rooted in the concrete and specific circumstance; and problems of individuals, social sectors, and local, national or regional communities. It should aim at having both the different human groups and each individual achieve enlightened awareness of their or his socioeconomic, cultural, and political situation, and of the factors and mechanisms which operate to conform it. It should aim at having each person acquire the mastery of the tools needed to operate in the different spheres of activity.

Even though it is stated that an education relevant to the majority is a necessary requirement, this must not obscure the fact that, ultimately, education, must be relevant to the people involved in the process. It must respond to the motivations, needs, possibilities, and purposes of each individual, even though this process of self-realization must be carried out deliberately and concretely in and through social interaction and solidarity.

National and Global Issues

In spite of the increasing openness and the tendency toward regional integration and international bonding of countries, the problems related to national identity and to domestic issues in each country should continue to be the nucleus of education. However, great care must be taken to avoid that conservative positions while appearing realistic or pragmatic in nature, may be masked in such a way that they appeal to traditionalist. It has to be very clear to all concerned that this sort of position usually brings about the contrary of effective independence and self-determination of nations, and thus becomes as self-defeating as the uncritical acceptance of models which have been successful in other areas or in other countries.

The global dimensions of the society, the close links and interaction existing among its components as well as the worldwide communication networks, underscore the existence of common problems affecting all or most of the world's population. This fact leads to the development of transnational curricula for these common problems. Nevertheless, the treatment of the various questions involved will vary according to the cultural perspectives and situations of the regions or countries concerned.

Capacitity for Mastering Communication Means

Participation implies the ability to master efficient communication in the different spheres of activity and insertion groups. The attainment of this goal is a key point of privileged education. The assertion, liberation, self-reliance, and self-determination of individuals, groups and nations presupposes a full command of the language at its different levels, and also a command of the languages of mathematics, science and technology, statistics, information science, politics, economics, and mass communication media. Obviously, it is necessary to be literate in terms of spoken and written language, and also to be well equipped for diversified oral expressions. This must be stressed as a central point of the type of education proposed. Also, it is necessary to be literate in the many other symbolic systems and codified signs of each society; in the non-verbal languages of art, sports, gesture; and in the global actions which give expression to the multiple roles, both existing and emerging, of a diversified and mobile society.

Orientation Toward Achieving a Generalized Quality of Life

In the Model the center of gravity shifts from mere quantitative growth to qualitative expansion, focused on the quality of life, and on the achievement of full human fulfilment; it seeks a generalized well-being in a non-consumerist society based on the use rather than on the possession and cumulation of goods. From this vantage point it becomes crucial for education to grant priority to the satisfaction of people's basic needs. That means giving priority to actions related to physical and mental health, and leading to prolongation of life expectancy. In short, an education is sought which will enable people to live a long and satisfactory life.

Achieving these aims is not thought of as a benevolent concession from those in power, but rather as a result of people's full participation in the decision-making process, and the programming and the controlling of the pertinent social actions. The education envisaged goes far beyond satisfying basic needs: it seeks to bring about the development of rich and expansive personalities in a social setting offering increasing opportunities for a fuller life. To achieve this it is necessary to develop rational and flexible thinkers alert and critical minds. This endeavour calls for a return to the natural life, to de-emphasize work as life's central value, emphasize the importance of expressionism, creativity, physical and manual activities, voluntary social action, relaxed meetings recreation and play, so that life can be lived fully, joyfully, and creatively, in an open, spontaneous, and liberated style.

Freedom from Dependence and Opportunities for Liberation

The society envisaged attaches a positive value to a liberating education of individuals and nations. The education project strives to develop people and social groups with a clear consciousness of themselves and their roles in society, to instill in them a desire for truth and self-determination, and a commitment to improving the world. It will therefore be necessary to first overcome the structural schemes and the "modus operandi" of the school, which usually operates as mechanism to maintain the established order, exercising authority in different ways to obtain adaptative behavior, obedience and dependence.

Three issues seem to be central on this respect. The first is the socialization process. It is necessary to overcome the authoritarian imposition of norms and rigid patterns of behavior with the correlative reward for blind acceptance and submission, and to introduce opportunities and mechanism providing chances to participate in controlling the ruling systems applied in the various educational situations. The second issue is the curricula. The proposed formula favors flexible, diverse, open and unbounded curricula, which is a change from the present rigid, uniform, prescribed, consolidated closed curriculum.

Concerning contents, in spite of recognizing the importance of a solid scientific and technological instruction, we believe that social sciences (together with language teaching) will develop into the critical nucleus of the curriculum in the preferred society (and particularly so during the transition period of the envisaged future). Seldom can one find a generalized treatment of present social reality and its prospects using the conceptual and methodological tools of empirical sciences. Although this approach is important in every country, its application is particularly relevant to developing countries, since it may favor the awareness and understanding of the crucial social problems affecting them; these problems include those related to the "history" and "geography" of inequality, hunger, sickness, poverty, ignorance, and scarce participation in the exercise of power. Very often, to not include concrete issues of social reality in the curricula constitutes a powerful weapon of domination. The third issue is technology of education. Contrary to the present practice, we believe that learning on one's own, and reciprocal learning should be the focus of educational technology. Especially because this constitutes a mechanism for liberation, and because the long process of post-school education will be carried out to a large extent independently and untutored. In the new setting, the role of the teacher will become that of an expert and guide whose main function will consist in helping people to obtain and process information so as to organize or reorganize their own behavior.

Equality of Opportunities

The attempt at achieving an equitable society, and at overcoming inequality must find its expression in the education sector. The way to do this is to replace the present educational policy (which upholds the right to an equitable distribution of educational goods, services and benefits) until a policy based on the recognition of the right of individuals to assume responsibility for participating in the construction of the world of education. This implies far more than guaranteeing the right to request an equitable distribution of opportunities from those who are in power; it implies exercising power by means of participation in the relevant decisions to generate, use and benefit from the opportunities.

In the future society, the proposed life-long educational scheme aims principally at insuring an equitable distribution of the educational opportunities and benefits among young people and adults. The privileges of today's young people constitutes an obvious point of inequality. Also, since the social projects are managed by adults, if these people are not offered adequate and sufficient education, the process of liberation and progress toward the desired society will be delayed or hampered.

In the envisaged future, adult education when limited to compensating for serious educational gaps, is unacceptable. For everybody, young and adult, education should be based on a scheme of multiple, open and unrestricted opportunities of equal quality and level, and for unrestricted and multipurposes.

In generally, the strategies aimed at the democratization of education concentrate on the school system and the young people. The problem is normally approached from a quantitative point of view: more opportunities are offered to more people, either enlarging the supply or facilitating and/or liberalizing the access to the system. In the envisaged education scheme the qualitative aspects will come to the fore; thus attempts, will be made to move from equality of opportunities of access to education to equality of opportunities of educational permanence and achievement. And the guarantee of an effective equality of opportunities in the access, permanence, and achievement will be offered to the whole population, regardless of age, and in both the school system and the out-of-school services. Since the educational complex will not only be far more reaching than the present one, but also the school system and the out-of-school services will progressively be integrated into an educational macrosystem.

NEW DIMENSIONS OF THE EDUCATION COMPLEX AND INSTITUTIONALIZATION OF AN EDUCATION MACROSYSTEM

The considerable increase in the volume of the clientele with respect to the traditional education complex (especially as a result of the presence of adults in the educational arena), the explosion of non-formal and informal education, and the heterogeneity of the needs which must be satisfied in a lifelong educational system lead to an appraciable enlargement of services. Thus the educational complex is broadened because of: (a) the growth of the school system which not only serves the young population but also the "recurring" adults; (b) the integration of out-of-school programs and services (mass media, job training departments, voluntary associations, etc.); and (c) the inclusion of support services so far considered peripheral such as publishers and producers of teaching materials, information and documentation services libraries, museums, institutes which produce educational knowledge and techniques, finance institutions.

The education complex tends toward a progressive integration, through the establishment of regular and lasting reciprocal relationships among its components. The bonds among groups of services allow for the construction of systems which in turn interrelate, thereby generating an education macrosystem (M.Marien). The school system, the on-the-job training departments, the educational services of the mass media, as well as those of the voluntary associations and other agencies already mentioned make up this new comprehensive educational system where the educational functions of society are distributed in an uncoventional manner.

It is foreseen that in the future society this educational macrosystem will be institutionalized by means of descentralized agencies of government, management and implementation in which the participants will be the institutions, the consumers, and all those involved in and affected by the educational activity.

It is expected that this macrosystem will function according to the criteria of openness, flexibility, diversification, integration and dynamism, and will allow for the free use and exchanges of the services offered. Likewise, it is assumed that operational schemes will be based on "multilocation," the use of multimedia, modular curricula and capitalized units, as well as on open activities free from the prescribed patterns with respect to time, age, place, curriculum, standards of achievement of tutelage.

FORMALIZATION OF THE EDUCATION SECTOR

For the starting year of the Model (1960) we used the available data on the enrollment rates of the population from 6 to 17 years, as well as the percentage of the GNP assigned to capital and the labor force of the education sector.

Based on these data, the relative price of the mean cost per pupil per year was calculated from 1960. For the following years, given a certain allocation of capital and labor, and knowing the price per pupil, calculations were carried out to determine the number of students, at the basic level, that the education system is able to afford. This datum and age structure allowed us to calculate the next year enrollment rates.

The costs of the three other categories into which education was divided in the education sub-model (secondary and higher, continuing and compensatory education) were included in the economic sector covering consumer goods. Since the services of transportation, communications, and the like are considered absolutely essential, the following constrain was set: yearly percentage of participation of these services in the GNP is not allowed to be less than the one allocated to it the preceding year.

As soon as the basic needs are satisfied in quantitative terms, the yearly unitary cost of basic education for Latin America, Africa and Asia is accumulatively raised 2 percent, up to the limit of US$ 150 (1960) per student, so as to increase the quality of education.

The existing relations among education and the GNP, expectancy of life at birth, urbanization and participation in the labor force by age groups are shown in the table 3.

Table 3

Variables	Education
GNP	0.7547
Expect. of life	0.9186
Urbanization	0.7807
Years 10/14	-0.7719
Years 15/19	-0.1955
Years 20/54	-0.0953
Years 55/64	-0.3504
Years 64 +	-0.7329

Notes: Data for 121 countries in 1960.
The education variable has a mean value of 47.299 and a standard deviation of 28.995

Special Report of Alternative Runs

Graciele Chichilnisky
and Hugo Scolnik
(As Reported by G. Bruckmann)

In the model, a Cobb-Douglas production function without technological progress had been used for Africa and Asia:

$$GNP_i(t) = K_i^{1-\alpha i}(t) \cdot L_i^{\alpha i}(t) \quad .$$

This was considered justified on the assumption that, in the periods under investigation (that is, the next few decades), "technological progress" in the sense of a third term in the production function would be negligibly small in blocks 3 and 4 (that is the poor countries of Africa and Asia). Furthermore, this leads to more cautious results.

During the discussions the question was asked: to what extent might the results have differed if the model had allocated a technological progress to blocks 3 and 4, similar to the one observed in the industrialized countries during the past two decades.

To answer this question, additional runs were later undertaken (on 9 and 10 October 1974), under the following assumptions:

$$GNP_i(t) = K_i^{1-\alpha i}(t) \cdot L_i^{\alpha i}(t) \cdot \delta_i(t)$$

$$\delta_1(t) = 1.014^{t-1970}$$

$$\delta_2(t) = \delta_3(t) = 1008^{t-1970} \qquad t > 1970$$

$$\delta_4(t) = \delta_5(t) = 1.02^{t-1970}$$

for all four blocks.

The results for Africa and Asia are given in the tables 1 and 2 below.

Table 1. Africa, with technological change.

Year	LE	Calories	Housing	Enroll.	GNP
1970	46.6	2312	0.5	28	149
1975	49.6	2669	0.51	35	170
1978	52.6	3000	0.53	42.2	191
1985	67	3000	0.69	83	286
1990	73	3000	0.79	98	387
1995	74.7	3000	0.86	98	554
2000	75.5	3000	0.96	98	836

Table 2. Asia, with technological change.

Year	LE	Calories	Housing	Enroll.	GNP
1970	51.7	2054	0.45	45.1	88
1975	55.5	2398	0.49	54.4	102
1980	63.6	3000	0.55	75	129
1985	71.5	3000	0.62	98	176
1990	72.4	3000	0.68	98	253
1995	73.7	3000	0.77	98	391
2000	75.1	3000	0.89	98	658

As can be observed, under these assumptions Africa and Asia would be able to reach acceptable goals even without outside aid: a sufficient nutritional level is achieved by 1980; enrollment by 1990; however, housing and GNP lag behind for a longer time.

Discussion*

W.D. Nordhaus, Rapporteur

A speaker from the floor said that it was important to keep abreast of world modelling activity, to make judgments as to ongoing work, and to report on the value and the reliability of the work. He continued; "In Herrera's introduction there is a lovely passage about academic freedom. We all exist in the academic world using each other's work and finding each other's criticism helpful. Criticism is useful, you learn something, praise is useless, you learn nothing from praise. I address myself to three problems that I have with respect to this work; they are not political, and are not concerned with what is or what is not a developed country. They are problems of modelling.

"First, the group raises the interesting problem of normative versus explorative forecasting. It is useful to have one team working at full scale at the normative forecasting process, and I accept that every explorative forecast must contain a normative element since some kind of goal has to be defined. However, the normative exercise has been oversimplified. Now that the goal has been defined, the important question is to show that the goals are attainable, and to show the strategy for achieving these goals, taking into account the world as it is. Any attempt to ignore the existing competition and conflicts within society is too simple. These are the constraints that we have to consider. This criticism applies to many present efforts. Where are the people? Where are all the quarrels? They are going to happen long before anybody has reached these ultimate goals, and long before any of the resources have run out.

"Secondly, I am not sure whether the Bariloche model can be called a world model. As I understand the model, the four regions are considered autonomous units and there are no trade links, no political links, and no competitive links among them. This is a dismembered world.

"Finally, as a matter of scientific reporting, I am well aware of the difficulties that exist in a group that has an ongoing

*The discussion was culled from the transcripts, the quality of which was poor so that it was difficult to obtain an accurate account. Apologies are accorded to participants whose remarks are incorrectly rendered--Editor.

and enormous enterprise such as this one, that has to meet deadlines, and so forth. However we must not allow difficulties to interfer with our business as scientists to produce a high standard of scientific reporting. A good report should allow us to return to our laboratories to repeat the work that shows that the results are, in fact, reproducible. Then we can test the sensitivity, test the assumptions, and test for errors. Comparing what we have here with what the Pestel/Mesarovic group produced--presumably under equal stress and time presures--I believe that the Pestel/Mesarovic group has allowed for a clearer conception of the model as a whole. It is easy to understand Pestel/Mesarovic, and also to test some of the assumptions and some of their data. I would suggest that this is the real criterion that we in the world modelling business should adopt if, in fact, we are going to make world modelling respectable--respectable as science, as hard science, as political science, and, most important, respectable as a decision tool for those harrassed men who have to make decisions."

Another speaker raised questions concerning the food sector of the model. He noted that one of the constraints in the model is agricultural input: livestock is fed from the grazing of non-edible land and non-edible crop. The agricultural production that can be used as food for humans is not used to feed animals. Perhaps it was intended that dependence on food imports from another country is undesirable. The principle that livestock should not eat food that humans could also eat seemed to him to interfere with the efficient allocation of resources. He said that the purpose this restriction would serve should be expressed as the objective function, without building it into a constraint.

Belsey raised two points. First, I disagree rather strongly with Scolnik's notion that statistics have no meaning. It is certainly true that this model is without statistical specification in an exact sense. Maybe none is possible, but certainly that does not rule out a meaningful and descriptive use of the standard procedures of statistical reporting that would allow this report to be better understood and more meaningfully evaluated. There is an accepted way of putting across information to the public that in some way involves statistical procedures; this leads to a formal Bayesian way in which statistics should be applied to this model. The absence of this is a very fundamental shortcoming, and one that should be corrected. The second point is a logical one. Local instability does not involve logical contradictions, except perhaps at the boundaries where you go from a locally stable to an unstable region. Indeed, there are many logical possibility that correspond with locally unstable equilibrium, and these are encountered in economics frequently. They may not correspond to what we call rational behavior, but then nobody is assuming the world or any one nation is rational.

Another speaker added two brief comments. He thought the Bariloche group had shown that there is an alternative future, that mankind might try to construct a future that is not based on the logic of the last 200 years and which is more than Utopia. Secondly, he commented that if we are to learn about "non-consumist" societies it would be useful to have a dynamic analysis of values of a non-consumist society.

Herrera made a few final remarks on what the Bariloche group believed about the model. We have tried to show basically that the obstacles preventing the development of mankind are not physical. There are solutions from the point of view of material or physical constraints, but we believe that these solutions imply deep political and/or social change. Some people have said at this conference as well as at other meetings that our model is optimistic because it does not assume physical constraints to growth. We are not sure that our model is optimistic, for history has repeatedly shown that it is much easier for humanity to overcome supposedly physical obstacles than to change political and social organizations. We can state that the model is optimistic only in the sense that we believe the future of mankind depends on the human will. That is probably the only thing that is optimistic in our model.

"Now the question arises, will there be change without conflict? For underdeveloped countries this has little meaning, as we are in a situation of conflict. What happened in Latin America may happen in Asia and in Africa--that is, conflict because these countries are trying to reject a long history of misery and poverty. But this conflict will be ideological rather than physical. The conflict will not be limited to the underdeveloped world. At present there are crises also in the developed world as people reject many of the ways that were basic to the world. We are in a state of crisis. It is not a question of whether the world is going to change--it is changing, --the question is what kind of world will emerge from the change? That is the real problem, and in this context our model tries to interpret the feelings and the aspirations of the submerged part of humanity and of many people in the developed countries who want to change the situation. The things we propose in our model are simple: the essential equality of man; a society in which every human being has the right to participate in the social process; a world in which cultural diversity is important and permitted; the ability to reach real achievements in every field. We do not know whether this world is possible. History is not physically minded. We are just proposing a possible world. Whether that world is feasible or not will depend mainly on whether we have been able to interpret the real aspirations of mankind. It is said that the common people do not write history--but that they often make it! And the final decision is therefore up to them. Thank you."

Koopmans concluded the discussions, thanking Herrera and his team for the interesting ideas presented and explained. He gave a summary of some of the highlights of the model.

a) The use of life expectancy as proxy for the vector of observations and phenomena that make up the whole of economic and social development. In his opinion, this was a good choice--better than any other that had been made.

b) Emphasis on reducing inequality in the world. This he felt was an important point, and further efforts for world modelling should keep this objective in mind.

c) The study of sensitivity of the runs to the amount of economic aid, as well as the question of technological progress.

d) Expert evaluation of natural resources availability, as explained by Herrera.

There were several problem areas concerning the model that Koopmans noted.

a) The absence of any discussion about implementing solutions. The problem is too large and there were too many unsolved substantive aspects, as well as a lack of agreement among the many clients. He believed that the emphasis should therefore be on the feasibility and speed of attaining specified objectives.

b) The validation of the production functions and other relations should be the subject of further professional work.

Finally, Koopmans noted that IIASA was pleased to provide a forum for modelling work, and that further work was necessary. IIASA should encourage such work, especially in the domains of theory, measurement, and modelling, always mindful that its task is to increase the scope of international scientific cooperation.

PART II: REPORTS ON OTHER MODELLING EFFORTS

Project CRISIS

R.C. Curnow

Project CRISIS describes an empirical investigation of the behavioural properties of large complex systems which are often analytically intractable. Its purpose is to see if we can find new ways of thinking about modelling such systems, whether they be man-made, man x nature, or social systems. CRISIS is an acronym for Catastrophe, Resilience, Integrity, Susceptibility, Indomitability Systemics.

The stimuli for this project came from three sources:

a) Several papers, notably Ashby and Garner, *Nature*, November 21, 1970, and the various papers debating diversity and stability in ecosystems; also the debate on the Green Revolution;

b) Observations on the susceptibility of the U.K. economy to the occasional breakdown of single links, for example, the power makers strike, the critical nature of very large chemical plants, for example, Flixborough, to the chemical sector; and

c) Work at S.P.R.U. on the consequences of critical dependence on an impact for specific countries, begun before the oil crisis.

The resources consisted of two people who are experienced and trained in modelling, and are anxious to find more realistic approaches to world modelling. The work described in this paper, which will be described in full at the Jablonna Symposium in December 1974, is largely owing to M. Maclean, a research student working under the supervision of the author, and also to the availability of powerful large computers at the U.K. Science Research Council and the Programmes Analysis Unit at AERE Harwell.

The work which is not funded, is in the early stage and will be extended as long as interest in the project continues.

The basic problem is: can a large complex system be meaningfully described in short, i.e. in other words, can we usefully parameterize such a system with regard to the characteristics vaguely defined by CRISIS? What we have done is to produce random (or pseudo-random in certain cases) systems belonging to the class $(n, k, \alpha, \beta, 3)$ where these parameters refer to the connectivity matrix. Sub-routines exist to do the following:

1) Produce random matrices, still systems (two sub-sub routines);

2) Test stability via the Hurwitz criterion;

3) Transitive closure re-representation;

4) Matrix powering;

5) Produce adjacent classes in n, k, α, β. Signed diagraph capability;

6) Determine criticalness of elements;

7) Distribute redundancy;

8) Replace single elements by a population of elements; and

9) Fine structure constraints (particularly for eco-system modelling).

Preliminary results are promising.

Forecasting Work at the Science Policy Research Unit

John A. Clark

The Science Policy Research Unit was set up in 1966 to study science and technology policy, and in particular, the social process of research, development and the diffusion of innovations. These studies clearly require a multidisciplinary team, and a particular feature of the Unit is that members are drawn from a wide variety of academic backgrounds. Another feature of the work is that it inevitably has a "forecasting" element, since a policy study is essentially concerned with the future.

Our interest in future studies became more explicit when the Unit began in 1971 a long-term project called STAFF (Social and Technological Alternatives for the Future), funded by the UK Social Science Research Council. This was at a time when environmental concern was at its peak and much interest was being shown in long-term forecasting, particularly with the aid of computer models. It was felt that the first project within the STAFF programms should be a study of long-term forecasting, with particular reference to the then recently published world models of Forrester and Meadows. This resulted in a book called _Thinking about the Future_, published in 1973. Following this work, a review of forecasting methodologies was undertaken and the results are soon to be published. We have described below some of the thoughts contained in this work to indicate the lines along which the Unit is thinking.

Forecasting can be represented on a diagram such as Figure 1.

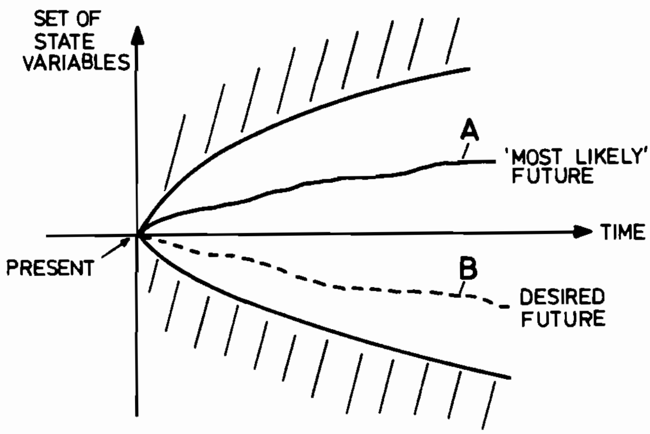

Figure 1.

Here line A represents an anticipated "most likely" future foreseen on the basis of current trends. Line B corresponds to a desired future which is attainable given certain changes of direction in society. The shaded area represents futures which are, for one reason or another, regarded as unattainable.

We agree with the Bariloche team that forecasting is essentially normative. Two important questions arise: what futures should be regarded as impossible? Where should the boundary lines on the above diagram be drawn? One can take a conservative view and say, for example, that the only alternative futures available to us are those within the present social and political systems, and with current technologies, which still leaves a fairly wide spectrum of choice.

The Bariloche team has opted to draw the boundary lines rather broadly; they have not recognized present social systems as unchangeable, although they have apparently been conservative on some questions of technology. We see the virtue of considering what might be called "utopian" futures, mainly because we see it more profitable to study ways in which a "desirable" goal can be approached than to assume in advance that processes which have operated in the past will necessarily constrain the future. Clearly these processes will change in any case, and our object is to see how, and to what extent, they can be purposefully changed to promote what we would regard as a preferable world.

Our approach is to set the general goal of reducing substantially the discrepancies in living standards between and within rich and poor countries, with a time scale of up to three generations. We differ from the standpoint adopted by the Bariloche team in that we do not assume a given political structure a priori, but will assess the effect of present and possible future political constraints to our goal as well as constraints of a physical, technological, economic and social nature. We shall probably use GNP to a great extent as a measure of well-being in the absence of an adequate quality of life measure, although we have one person in the Unit making a special study of alternative social indicators.

As to technique, in thinking about the future we have discussed both qualitative and quantitative alternatives available. These range from simple single-variable extrapolation, through "intuitive" methods such as Delphi and scenario writing, to mathematical methods such as simulation and gaming models.

It is very difficult to compare alternative techniques on grounds "accuracy". Examples abound of apparently ill considered forecasts being successful, often for the "wrong" reasons (for example "a lucky hit") while careful analyses frequently have yielded very poor results. Even the determination of whether a forecast has been "successful" is often difficult, because of its impact on the social process; forecasts can be self-fulfilling or self-defeating. Thus, "track record" seems to be an inadequate guide to assessment.

Other criteria, admittedly of a more subjective nature, can be used. Are data of the required type available, and is the quality adequate? Are personnel with sufficient expertise available for the duration of the project? Are the assumptions behind the technique acceptable? Are the results relevant and in a form useful for the purpose of the forecast? These questions can only be answered with clear objectives for the exercise in mind; in our view forecasting should be undertaken from a "problem-based" rather than a "technique-based" standpoint, the choice of methodology, or of groups of methodologies, being made according to the kind of criteria given above when the problem has been clearly stated.

The particular virtues claimed for mathematical methods are the following. First, it is asserted that such methods permit easy manipulation of a large number of interdependent variables simultaneously, and that this process frequently leads to results which are surprising or "counterintuitive." Secondly, the point is often made that such methods force a clear statement of assumptions and give results which can be reproduced and analyzed by other groups.

The first argument seems to be valid in principle, but there are dangers. A large model demands the use of many data and theoretical ideas of varying quality, and it is possible that a weak link in the chain can introduce "noise" and render all results spurious. Also, the behavior of a model is often largely predictable given one or two basic assumptions, and in practice is not "counter-intuitive." An example of this is the Forrester model; the assumption regarding natural resources makes industrial decline inevitable at some stage.

As for clarity, we think that the argument has some validity. Our reservations here are that those not familiar with mathematical notation would hardly consider computer models to be clear, and if the model is constructed for policy purposes debate among decision makers and the public is likely to be restricted. Also, many mathematicians used to working with equations in closed form would not regard a large-scale computer model as clear, and we know how difficult it is to investigate a large model thoroughly. The important factor here is the purpose of the model; loss of ambiguity may be of first importance in testing the inconsistency of theories, while lack of public comprehension may be fatal for policy making.

The overall feeling of our group is that a computer model should not form the basis of our STAFF study, but that models should be used for individual problems where appropriate. We believe that there is room for both qualitative and quantitative approaches to futures studies. The verdict on large-scale models as policy tools must be "not proven", although the method is such that criticism of individual models is easy, which to me means that progress is likely to be made.

For the STAFF study, the world is divided into nine regions, each of which is divided into subsystems such as food, energy and materials. We have subgroups within the unit working in each of these fields.

For these subsystems, there are certain common questions we shall consider, such as: what increases in production are needed above 1970 levels to meet the basic requirements of the population in a more equitable way? What technologies, either existing or potential, appear to be the most desirable for achieving this without undue human and environmental risk? What research and development programmes are needed to promote these new technologies? What social and institutional constraints hinder the development and application of desirable technologies?

We hope to have answers to some of these questions by mid-1976, when this phase of the programme ends.

Global Modelling in Relation to the Developing Countries

M.S. Iyengar

INTRODUCTION

This paper addresses several issues of broad concern to the developing countries: population trend, the quality of life, national development plans, problems of industrialization, and their relevance to the global concept of development.

On the analogy that people would never attempt to send a spaceship to the moon without first testing the equipment by constructing prototype models and by computer simulation of the anticipated space project, the MIT (Massachusetts Institute of Technology) School under Forrestor, Meadows and others developed the system dynamic computer models for the world which culminated in the prestigious publication *Limits to Growth* [1,2,3].

The major conclusions of this approach affecting the developing countries are:

a) There is no realistic hope for the underdeveloped countries to reach the standard of living of the developed countries, since their achievement of the economic levels of the USA would mean a ten-fold increase in the consumption of natural resources and an increase in pollution levels of the world's environment.

b) From the long-term point of view, the present effort of underdeveloped countries to industrialize along Western patterns may be unwise. In their present condition, the underdeveloped countries may now be closer to ultimate equilibrium with the environment than the industrialized countries.

The implications of the above statements are that the developing countries should continue to concern themselves with problems of agricultural self-sufficiency, and not with industrial self-sufficiency. Also, they should fulfill their needs for consumer goods by continuing to import them from the already industrial countries.

Many critics have pointed out the weaknesses in the MIT model such as apparent failure to give proper weight to negative feedback loops that naturally restrict growth and re-channel resources. Doubts have also been cast on the validity of the assumptions made in setting the relationship between the mathematical variables in the choice of initial conditions. Some critics used the language of MIT but, by making assumptions about the extent to which the capital resources will in future years be devoted to the abatement of pollution, have shown that feed-back loop is less vicious in its effect than has been shown. Some have strongly argued that the MIT approach is inherently dangerous, since it encourages self-delusion [4].

One of the serious limitations of the MIT model is that it fails to recongize that 80 to 85 percent of the total non-renewable resource consumption is by 25 percent of the world's population. A recognition of this fact would reveal immediately where restrictions would be more effective. As has been pointed out by Cole [5], a model which does not take into account the world heterogenity may be more than useless, and policy recommendations based on it may have less possibility of being accepted by the majority of mankind. Secondly, the MIT Group has underestimated the qualitative change that science and technology are undergoing and will continue to undergo in making production less energy-, resource- and pollution-based. Good examples of this trend are the thermionic valve versus the fourth generation LSI, and the recovery of copper from ores by microbial methods versus the present day smelting.

Nevertheless, the Club of Rome document is important as a graphic presentation of the thesis that more economic growth will not solve our problems and because it is a beginning of an understanding as to how the world system really works. The realization that we cannot solve conflicts by continuing to cut bigger and bigger pies in the same way must lead to a discussion of how to divide the pie more equitably. And indeed it is leading to this discussion. What then is the present day reality in the developing world?

THE PRESENT-DAY REALITY IN THE DEVELOPING COUNTRIES

The appallingly low subsistence level prevalent in the third world is a present day reality. These countries at present possess many or all of the following characteristics: low real income per head; an economy dependent upon primary products, natural resources not fully utilized to the benefit of the inhabitants; widespread unemployment; a limited amount of capital equipment in relation to number of workers; and a high proportion of the population engaged in agriculture. The annual earnings of an average Swiss National equal the combined average annual incomes of two Mexicans, two Ghanians, two Filipinos, four Indians and three Ethiopians.

The population in the third world doubles every 40 years. Most of the people in these countries are young, usually below 15 years of age. In countries such as Mexico, Ghana, Thailand and the Sudan, the percent of the youth population is nearly one half compared to one third in the USA and under one quarter in

Britain. This has repercussions on the available educational facilities and on the whole economy because youth does not contribute to the work force and has not acquired a work skill.

The full resources of the third world are not yet known. Large areas are barely mapped, let alone surveyed for minerals and oil; many rivers are not yet assessed for hydro-electric power and irrigation. However, what has been determined is the fact that the mineral, agricultural and energy resources of these countries are very large indeed. Food yields are generally one fourth or one fifth of those of the advanced countries. Over one third of the whole food grown in developing countries is spoiled by pests and rodents.

BARRIERS TO DEVELOPMENT

The people of the third world have a stupendous task of breaking through the interrelated barriers that bar their way to development. The barriers, in the words of Gunnar Myrdal [6] are:

> People have poor health and low energy; low energy results in low productivity which keeps people poor. Economic development requires capital; capital must come from saving; saving requires cutting down consumption--but a poor economy consumes most of what is produced.
>
> Low economic activity cannot create the tax base for producing the revenue required for such infrastructure investment as transport, power and education, which are essential to increase economic activity.
>
> Developmental activity is initially more effective in reducing death rates than in producing goods; consequently population increase and living levels are lowered.
>
> Development requires change but in the traditional societies power is often in the hands of those most bound by tradition and resistant to change. In other words, poverty is its own cause.

PLANS FOR DEVELOPMENT

The countries of the third world have diverse historical backgrounds and a variety of economic situations. They include some of the oldest nations and some of the newest, some of the largest nations in domain and in population and some of the smallest. Some are faced with heavy over-population, some with under-population and all have high rates of population growth. Some have readily exploitable and explorable resources such as oil to finance development; many others have difficulties scraping together an agricultural support for export. Nearly all these countries believe that rapid development will not just happen but that it must be stimulated, directed and controlled so as to make the best use of the resources and to share the benefits equitably. The plans, however, vary widely. Only a few are comprehensive or operational, in most cases simply because there are not enough statistics and material to draw upon and not enough people to put plans effectively into practice. Sometimes, the plan is little more than a list of projects to be undertaken by the states. Sometimes it is simply a program of studies.

India's Five Year Plan, on the other hand, is more comprehensive. It contains overall national targets and assessment of the resources available and of the investment both in public and private sector on major economic centers and policies to stimulate direct private investment as well as detailed list of projects in the public and private sector. But since the growth rate envisaged is very low, the Plan is not able to keep pace with the rising population and therefore progress registered is not very rapid. Also these plans are not "operational." That is, there is no system to see that what is planned is achieved. There is no deterrent to non-fulfillment.

Of the resources available for investment in development, a certain amount must be in foreign exchange so that goods and skills which are not available locally can be imported. The shortage of foreign exchange is one of the main problems of the third world.

Governments in most of the countries of the third world do much more to promote economic development than do governments in the advanced countries and much more than it is usually supposed that governments did in western countries, at similar stages of their development. This is mainly because of the large priority that must be given to roads, railways, harbor, power generation and distribution, communication, irrigation, industrial estates and the like. The investment for such facilities in most of the countries account for about 50 percent of the total investment. Secondly, government participation in the transfer of technology is also large-scale. Most governments of the developing countries need the blessings of a modern welfare state--that is, old age pension, unemployment insurance, family allowances, health insurance, 40 hour work-week and so forth. In western countries a sustained growth in national output attended the spread of the social services of this type. In third world countries, provision of these services here and now becomes a political necessity.

WAY OUT FOR THE DEVELOPING COUNTRIES

What then should be done? What path of development should be followed? Should they follow the path of industrial growth pursued by the affluent countries? Is this feasible and desirable? First and foremost, it is obvious that the developing countries should not have an uncontrolled consumer and market oriented growth. It is also obvious that they cannot create symbols of modernism in a few places and leave "ghettos" of ignorance in vast areas. It is also obvious that the trend toward urbanization with its hungry millions living in a horrifying belt of slums around the glittering moneyed core has to be reversed. This much is obvious, but would the solution lie in a return to the homogeneity, uniformity of social constraints of the pre-industrial peasant enclave?--a theme often romanticized by those who did not have to endure it.

At this stage we should recognize the changing profiles of technologies since these cannot be ignored in any scheme of modelling. As has been pointed out by Bernal [7], and later by McHale [8], the so-called limiting characteristic of industrial technology are actually extensions and adaptations of the older craft production techniques--the factory system with its routinization of work, the location of population and industry in the proximity of raw materials and energy sources.

For most of this first generation technology industrialization was based on the fossil fuels and even today constitutes much of industrial growth. Electronics and nuclear energy, computers, synthetic materials such as plastics constitute the second generation of industrial technologies which emerged after the Second World War. To quote McHale [8], "...the emergence of information and information technologies as the key resource changes the old pre-industrial zero sum game conditions of society into what has been termed the post-industrial phase--into a non-zero situation in which all may potentially win." Electronic technology already makes less energy demands. However, the third generation of industrial technologies as exemplified by industrial microbiology promises to be the least demanding on the energy and raw material resources with lower environmental impact. The wider use of microbiology for production of food, energy, processing of material and the like is an area which is opening up possibilities of alternative technologies to which the developing countries should turn their attention.

Unfortunately, however, quite the opposite is happening in the developing countries. Only those obsolete technologies of the first generation which are most demanding of resources and most damaging to the environment are being advocated for use. Dr. Mehboobul Haq, a Senior Economic Adviser to the World Bank, anticipates that as pollution control becomes more stringent in the rich countries, they may drive away such industries as petroleum refining, chemicals, metal extracting and processing, and paper and pulp to the huge open and sparsely populated space of the Third World [9]. Some people in the developing countries seem to welcome such a proposition since according to them this would provide employment in areas threatened with unemployment.

While the developing countries should certainly guard against the temptation to follow the path of development of countries such as the United States and should stop creating a world of Cornocopia, they should nevertheless pay attention to satisfying the basic biological needs of food, shelter, clothing, health and education of their citizens.

EVOLUTION TO A POST-INDUSTRIAL SOCIETY

The possibilities of the developing countries evolving directly into a post-industrial society have been discussed at length (see for example [10,11]). Some of the salient arguments in favor of this direct transformation are discussed below.

The object of all social goals is to create conditions where man would be freed of struggle, and for the first time, free from biological needs; thus he would be free to choose the style of life that he wants. It would be a society which would stop making a non-human use of human beings and where the creative faculties will have opportunities to blossom. It will be a society which would accept the idea of "protein man" as part of a "protein society." For this to be possible, the developing countries should attempt to go from pre-industrial form to post-industrial form in one transformation stage of development. The developing countries should stop all attempts to solve problems of unemployment in the classical sense. By employment they mean manual labor. What they should aim at is to create conditions where the creative faculty which is human comes into play and in that sense the society would be "unemployed." This could be possible by adopting cybernation and automation, for cybernation produces goods within reach of the common man with less inputs than the mechanical means of production.

The first generation type of industrial production is more efficient as it grows larger in size and becomes more specialized--an effort which is more capital-intensive and for which giant manufacturing capacities have to be created which are only possible in the developed countries. Automation is an alternative method. Its emphasis is on scaled-down production and a return to general purpose handicraft flexibility; thus it is well suited to the developing countries. The developing countries should not be haunted by the specter of unemployment. In any case, unemployment is increasing despite the present methods of development. By making production more labor-intensive, efficiency of production is sacrificed. Let it not be forgotten that manual labor is equal to one-fifth of horse power.

Since the advanced countries are emerging into a society which has been termed a "learning society," the developing countries should also directly emerge into a learning society. For instance, by modernizing communication systems through communication satellites, the developing countries could modernize their villages and prevent urbanization.

Communication also would pave the way for reform in education. Audio visual education through TV and satellite could overcome the language barriers and carry the message directly to students. Education through TV will be much cheaper than the conventional form of education. As has been clearly shown by a UNESCO study, while only 10 percent of the area and 25 percent of the population would be covered by conventional educational methods by 1981, through a satellite system the Indian villages could have a two-hour TV program and the cost involved would be equal to the cost of three supersonic aircrafts, or in monetary terms, just $160 million. Education need no longer be imparted at school. A person should be in a position to educate himself at home assisted by computer-aided education, electronic video recording machines and other technical aids. The developing countries should utilize judiciously and prudently the "hardware" that the new technology offers and pay much more attention than the developed countries to reconstructing the "software" or social thinking, and making it more meaningful. All this means that they should make socio-ethical decisions regarding human conditions not in terms of what they can do but in terms of what they choose to do both individually and collectively. Their planning should not be geared to any specific set-up of fixed or pre-formed objective. Rather it should be based on a set of options and alternatives taking into account the socio-economic cost benefits. The developing countries already have the outer manifestation of a post-industrial society. The majority of these people are unemployed or under-employed in the economic sense, and, to a good number of them work is not the central life interest. The principles of rationality and efficiency and the notion of time as money, that is, as a scarce commodity and socially significant unit, do not exist. These are the very manifestations of a post-industrial society. Adoption to similar conditions would therefore be easier in the developing countries than in the developed countries.

The question often asked is what about the financial resources? Where would they come? The answer is that sophisticated third generation technology is much less capital-intensive than the first generation technology. For instance, the inputs needed for manufacturing a transistor radio set are much less than the thermionic valve set. Secondly, the developed countries should help the developing countries in this transformation. It is in their long-term interest to remove the "imbalances," for this is vital to any global concept of living.

Finally, the problems of developing countries cannot be separated from the problems of the developed world. Their problems are inter-twined and are part of the same global problem. While the solutions to the problems of the developing countries cannot be wholly based on the models of the developed countries, the problems mentioned in *Limits to Growth* of the developed countries should not be blindly imposed on the developing countries. The developed countries should go slow on further depletion of resources, and model their development toward improving the quality of life. They should adopt for conversion from what Ehrlich calls the "cowboy economy" to a "spacemen economy" with dramatic change in the concept of needs; seeking as a nation growth of the individual rather than freedom of the market and growth of economy and industry. For "more and bigger is not necessarily better" [12].

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Non-Economic and Economic Factors in Societal Development: The General Production Function

Christof Gaspari and Johann Millendorfer

CONCEPT

The development of the General Production Function is based on an understanding of the functioning of societal systems in general. Therefore, we think it useful to start with some remarks on the underlying concept. First, it should be noted that society can be thought of as a complex, multihierarchical system. This system is characterized by the interaction of a great number of subsystems, and it is this interaction that enables the overall system to function. Economy is one of these subsystems. Therefore, if we want to understand how this subsystem works, we must go beyond the economic sphere proper and consider also the interrelations with other subsystems.

Society has another characteristic feature in common with other systems, namely its ability to process energy and information. The economic output of a social system is therefore governed by its capacity to cope with these two fundamental processes. Argumenting in such a way we are applying a concept which clearly shows the influence of Deutsch [16] who understands society as a self-developing cybernetic system. There is a system of information receptors, information channels, information storing units and logical units that is superimposed on a control system, in which the material processes take place. This network receives information on the actual situation, on environmental changes and on the internal structure of the system. It then processes this information using additional information stored in the past. This process gives rise to new information which regulates the measures to be taken, that is the commands given to the control mechanism.

The energy processing capacity of a system as well as its capability to master information are not sufficient to determine a system's economic output. A third component is needed to describe adequately the complex processes mentioned. On the one hand, this third factor reflects the objectives toward which the efforts of this system are directed. On the other hand, the way the system is organized, that is, the regulation and coordination of the energy and, in particular, the information processing operations, should play a certain role. These two components are the chief determinants of the third factor, namely, structure which describes the objectives of the system, the organization of its energy and the data processing subsystems that correspond to these goals.

This model, of which only a short outline has been given has served as a basis for investigating the societal subsystem economy. The sections that follow will show how a country's economic performance can be described as a function of its energy and data processing capacity and of its structure.

THE FACTORS INFLUENCING ECONOMIC DEVELOPMENT

Applying the concept described above to the study of economic development, we can formulate the following hypothesis:

$$y = F(m,b,p,r) \quad .$$

where

per capita income (y)	= economic output,
energy consumption (m) (capital)	= energy processing capacity,
education (b)	= data processing capacity,
structure (p)	= values, type of organization, types of behavior,

and mineral resources (r).

We have made use of some of the above mentioned production factors with the exception of "structure."

Capital

The factor capital--which, as will be shown below, shows a close correlation with energy consumption--constitutes a common component of almost any economic production function. The relationship between capital input and economic performance has been dealt with in a number of previous studies, and we also find attempts to measure this relation on the basis of international comparisons. A study by Galenson and Pyatt [15] is such an attempt to test the assumptions underlying the theory of growth by means of an international comparison. Thereby it has become apparent that too simple assumptions are not suited to explain the international differences in economic growth (see Figure 1). Obviously this study has run into difficulties. The authors are confronted with problems similar to those encountered in many other studies, relying on international comparison as means for testing their hypotheses. For the most part these studies have not succeeded in taking account of the great number of geographical, cultural, climatic and political differences among the individual countries of their sample. In other words, the observed differences in income (dependent variable) result from heterogeneous influences which cannot be adequately explained by differences in capital inputs. They must be explicitly controlled and entered separately into the study. Not taking care of these influences corresponds to a non-fulfillment of the ceteris paribus condition.

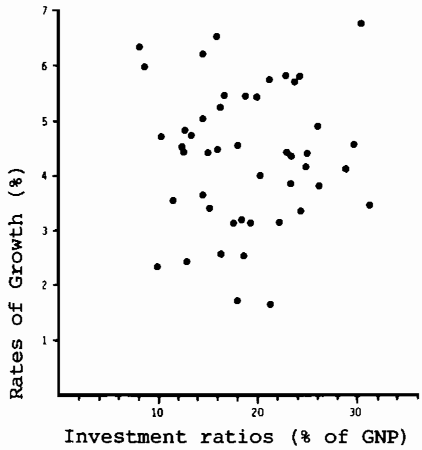


Figure 1. Investments and growth rates in the countries of the world.

Structure

This gives rise to the demand for an efficient methodology which takes account of these various influences. One such method would undoubtedly consist of forming groups of countries within which the combined effect of these nonobserved but relevant influences on each country is nearly constant.

An important clue for the formation of such groups of countries could be provided by observing the health development in the different countries of the world since the beginning of this century. The time series from all countries of the world for which figures are available have shown that the development of health is fairly uniform within groups of countries, these groups being at the same time sensible geographical aggregates. The differences between the groups are large enough to decide to which group a specific country actually belongs.

Without going into details of the problems encountered here, we may interpret this observation as follows: health statistics provide one fundamental indicator of the development of a society. Here we are measuring the "pulsation" rate of the societal system as it were. It is governed by many factors which cannot adequately be measured directly. We may consider the adoption of medical innovations as one part of innovations in general, which we call a "learning process." Thus, the regions differ as to their readiness and capabilitiy to adopt innovations. This general statement is based on the observations made in one subsystem of the society, namely the health system. For it is the greater or smaller readiness to adopt medical innovations that is responsible for a more rapid or slower improvement of health conditions.

We can assume that the "structure," that is, the value system, the patterns of behavior and the types of organization, constitute an important factor responsible for the differences observed with regard to the development of health. Using this methodology we found 14 groups of countries with different "structure." The European countries can be classified into three zones according to their different health development (see Figure 2).

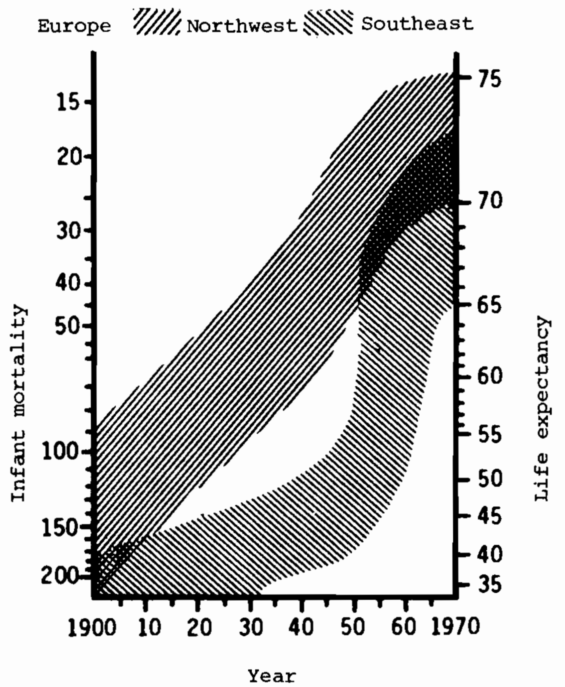


Figure 2. Health development in Europe. There are three zones, Northwestern, Southern and Eastern Europe; Southern and Eastern Europe show similar development.

If we apply the classification of groups of countries as presented in Figure 2 to the data of Figure 1 to separate the two groups of European countries, we arrive at a meaningful relationship shown in Figure 3. The regression lines showing economic growth per unit of investment lie on different levels in countries with different political and cultural systems. This observation suggests that the differences of the political and cultural structure affect the effectiveness with which capital is used, and thus affect the energy processing capacity. In addition, the evidence presented gives rise to the methodological remark that reliable results in international comparisons can only be obtained if due account is taken of the ceteris paribus condition.

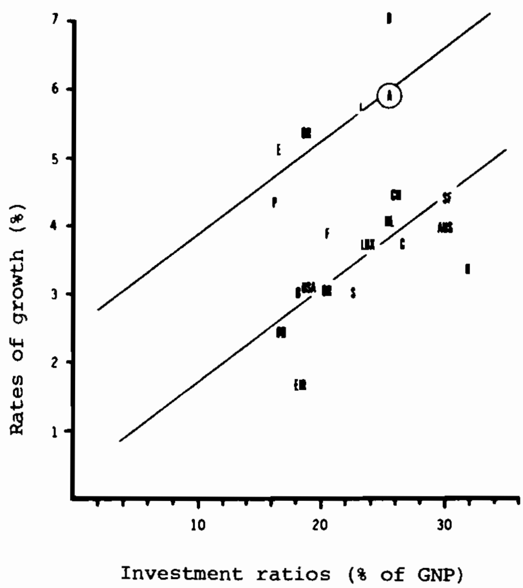


Figure 3. Investments and growth rates in two groups of European countries. Data are taken from Figure 1, and show that meaningful relationships exist within groups of similar countries.

Education

The majority of the studies carried out to date have considered man as an element of an undifferentiated factor "labor," and have used the number of people in the working force as one of the input factors. Various abilities, differences in the level of education (which correspond to differences in information processing capacity) have so far been neglected or have not been examined in relation to the other factors. But if we look at Figure 4 we find that it is obviously a country's level of education which is very significantly correlated with its economic performance; therefore, this factor has to be included in a production function.

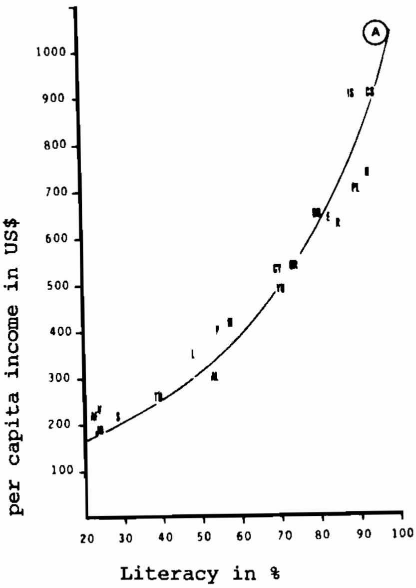


Figure 4. Per capita income and literacy rates in groups of countries with similar structures. The figure shows the close fit to the exponential relation between the economic output and the level of education.

Closer examination of the relationship between education and income in a cross-section of countries reveals that the aggregation of countries according to the criterion of similar health development is also good for this purpose. The regression coefficient of the education is practically the same in all the regions. (Regions are defined by the criterion of equal health development.) The intercepts of the regression lines, however, differ from one zone to the other. Significant differences do occur only between five large zones of the world.

The evidence presented thus far can be summarized as follows: There is sufficient empirical support for concluding that a country's economic performance is mainly determined by three factors, namely capital (energy), education (information) and structure.

Natural Resources

Examination of the output differences among the countries of the world reveals that, apart from the factors discussed, the occurence of mineral resources is an additional relevant factor. The important influence of mineral resources on the level of economic output is supported by observations in other regions, in particular in the countries of the Near East and in Africa.

Combining the Factors

If we now combine all the individual factors mentioned separately, we obtain a functional relationship which explains the international differences in economic performance. The combination of capital, education, structure and natural resources has a much higher explanatory power than the simple regression of a single factor, as may be seen in Figures 5 and 6.

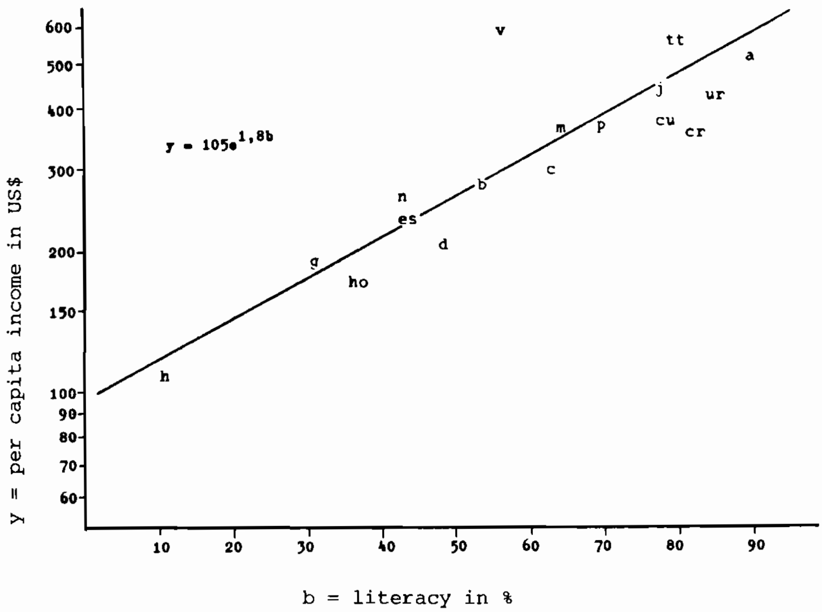


Figure 5. Special position of Venezuela (v), Trinidad and Tobago (tt) in the comparison of per capita income and literacy in South America. Venezuela's large deviation from the regression line is striking and can be explained, even quantitatively, by this country's important oil production.

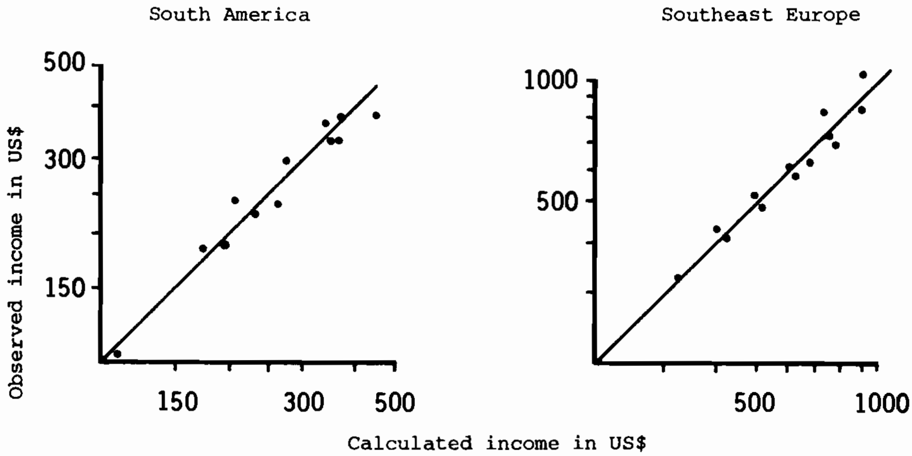


Figure 6. Comparison of observed per capita income and its estimate as calculated value. (Account is taken of all the factors which when combined yield a much higher explanatory power. Discrepancies between observed and calculated values are insignificant.)

Mathematical Expression of the General Production Function

The individual factors are combined by means of the so-called General Production Function, which has the following mathematical form:

$$y = P_{t,z}\, m^{\frac{1}{4}}\, a^{\frac{3}{4}}\, e^{b} \left[\frac{1}{2}\left(\frac{m^{0,25}}{e^{b}}\right)^{-9} + \frac{1}{2}\left(\frac{e^{b}}{m^{0,25}}\right)^{-9} \right]^{-\frac{1}{9}} + 0,8\, r \quad , \qquad (1)$$

where

y ··· per capita income, measured in US-dollars per inhabitant (annual),

$P_{t,z}$ ··· efficiency parameter,

a ··· employment ratio,

m ··· per capita capital input, measured by means of energy indicators,

b ··· qualification of labor, measured by using educational indicators,

r ··· natural resources index, measured by the value produced by mining operations, etc.

Expression in parenthesis: limitationality parameter. This describes the diminishing efficiency of additional input units of capital or educational effort when departing from the optimal relationship (see below).

The exponent of m and the coefficient of b have been estimated in a cross-section of countries by econometric means. While the parameters are not exactly 1/4 or 1, respectively, they do not significantly depart statistically from these values used for the sake of simplicity.

STRUCTURE AS A FACTOR INFLUENCING THE PRODUCTION

The Efficiency Parameter $p_{z,t}$ and Structure

Measured in a cross-section, the efficiency parameter $p_{z,t}$ of the General Production Function is the same for all countries belonging to one group at a given time. As previously stated, analyzing efforts in the field of health makes possible a division of countries in 14 distinct groups. Some of these groups have very similar efficiency parameters and thus can be aggregated into greater zones. The characteristic trait common to all component states of each greater zone is a constant relationship between capital and educational effort, and economic performance. Countries within each zone are using capital and education with equal efficiency.

In the mid-1960's, using these criteria, the world could be divided into five greater zones with differing efficiency parameters as shown below in Figure 7. The zones with differing efficiency parameters were calculated using data for per capita income, education, capital and natural resources.

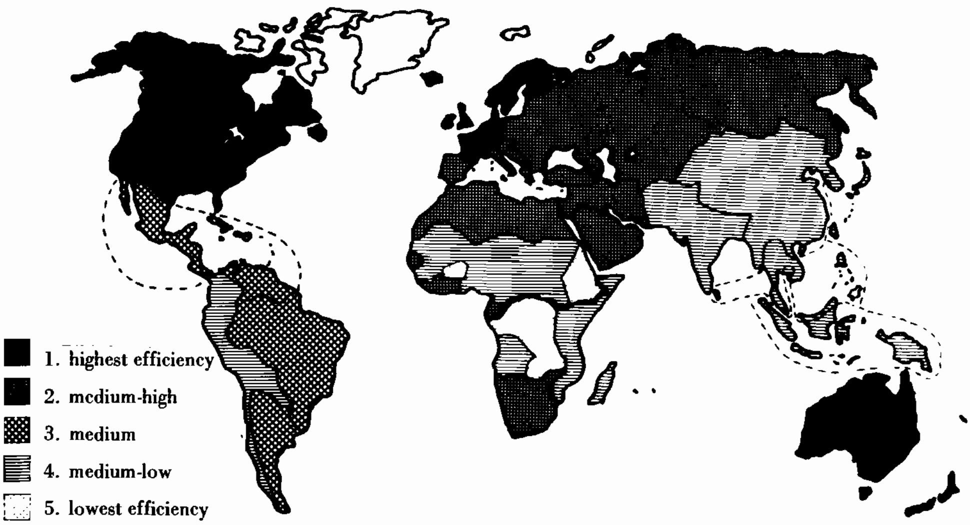


Figure 7. World divided into five great zones.

These five greater zones have different culturally determined behavior patterns, systems of values and organizational structures. Different efficiency is connected with different structure.

Technological Progress and Structure

The efficiency parameter is constant for the countries in a greater zone. But if we observe time series, the efficiency parameters of the greater zone increase with time. That means that we have a residual in the time-series not explained by the production factors of the General Production Function. According to the usual terminology we call this residual "technological progress"; this technological progress is different in each greater zone (see Figure 8).

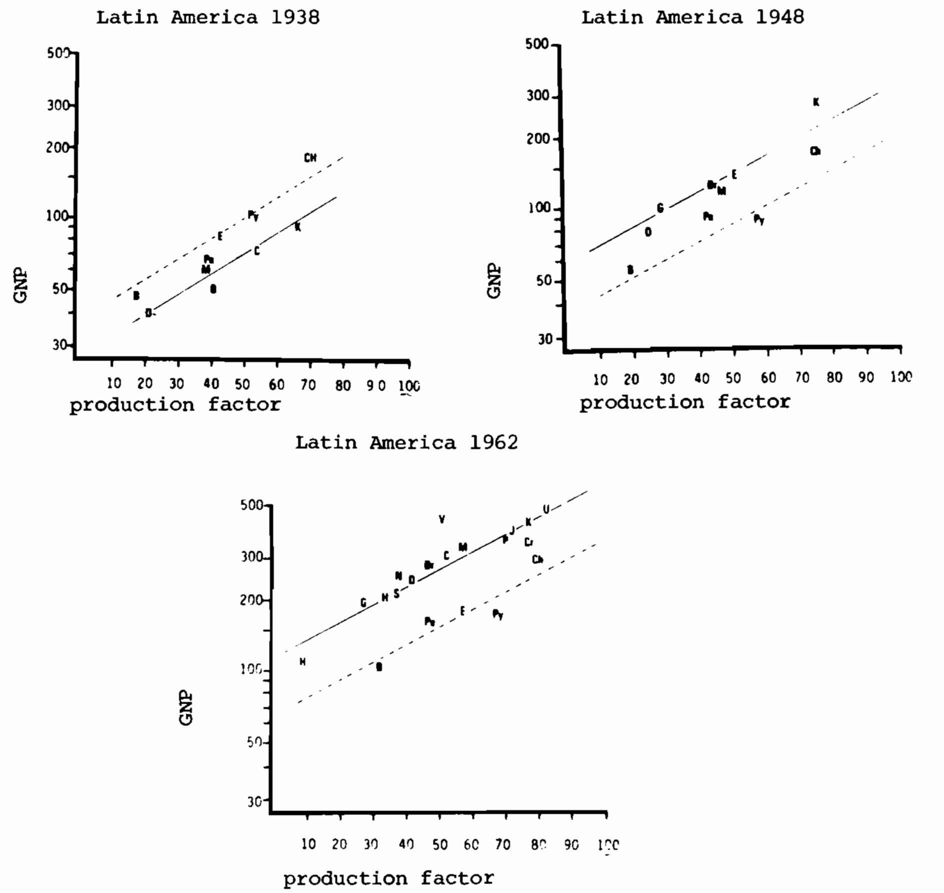
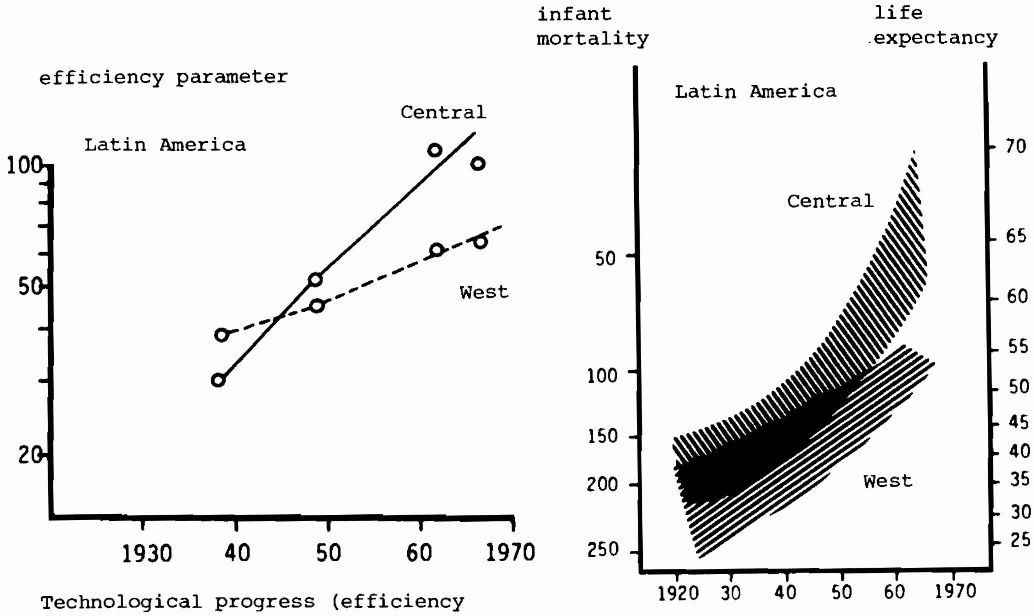


Figure 8. Different growth rate of efficiency parameter of General Production Function in two Latin American zones. Efficiency parameter is represented by level (intercept) of regression lines. Solid line: Latin America, Central and East; dotted line: Latin America, West.

Different structures are connected to a different "technological progress."

Advances of Knowledge and Structure

An interesting observation is that, in a greater zone, the technological progress measured by the growth of the efficiency parameter of the General Production Function is similar to the medical progress measured by time-series of health indicators (see Figure 9).



Technological progress (efficiency parameter = level resp. intercept of the regression lines of Figure 8)

Medical progress

Figure 9. Similarity of technological and medical progress in the two Latin American zones.

This leads to the theory that behind both kinds of progress lies the ability to accept advances of knowledge and that the speed of this acceptance is influenced by culturally determined behavior patterns, systems of values and organizational structures. The different regional acceptance of world-wide advances of knowledge is connected with different structures.

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Modelling Resource Problems[1]

P.C. Roberts

ABSTRACT

The requirements for modelling physical resources are presented in terms of a conflict between depletion making exploitation more difficult, and technological advance which is acting in opposition. It is argued that an input/output basis is most suitable for the structure of resource models designed to study substitution. Results obtained with such a model have indicated sensitivity to the discounting rate employed.

DEFINITIONS

By "resources" is meant minerals, cultivable land, energy sources and water. Although skilled manpower, capital equipment, knowledge and even the genetic pool have been classed as resources in other contexts, they are here regarded as peripheral to the main topic.

The problem is that of maintaining a given level of continuity in supply or, more specifically, of avoiding the hardship associated with abrupt and acute shortage.

The objective of modelling is to gain insight into the interactive effects governing the onset of shortage and, potentially, to discern those parametral changes in the control elements which would offset the effects of shortage.

INDICATORS OF RESOURCE PRESSURE

There are two opposing effects whose joint action is manifested in pressure on resources. The most obvious one is that progressive exploitation of a given resource results in increasing difficulty of the exploitation process. As an example,

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[1]This paper has also been presented at the Operational Research Society National Conference on 22nd - 25th October 1974, Brighton, England. The views expressed in this paper are those of the author and do not necessarily coincide with those of the Department of the Environment (London).

the following table shows the decline in average grade of copper ore mined in the U.S. with cumulative extraction.

Table 1

Cumulative extraction million tons	Grade % copper
0	2.0
6	1.4
10	1.2
15	1.0
23	0.8
37	0.6

The opposing force lies in the technological advance through which higher efficiencies are developed. For example, the gross energy requirement per unit of product for a range of commodities has been calculated from U.K. input/output tables in 1963 and 1968. The figures in the following table refer to all the prime energy sources (coal, gas, oil) used in all preliminary and final stages of production for each commodity.

Table 2

Commodity	Unit	1963	1968
Iron and steel	kwh/kg	7.09	6.60
Grain milling	kwh/kg	1.85	1.70
Cocoa	kwh/kg	18.5	14.3
Sugar	kwh/kg	5.35	4.44
Tobacco	kwh/kg	346.0	343.0
Cement	kwh/kg	1.64	1.58
Paint	kwh/gal	145.6	102.0
Man made fibres	kwh/kg	48.6	45.6
Footwear	kwh/pair	43.9	35.5
Paper and board	kwh/kg	11.8	9.9
Motor vehicles	kwh/car	19138	17758
Cans and metal boxes	kwh/kg	11.75	11.04
Water	kwh/1000 gals.	5.29	4.79

Source [1]

Technological advance encompasses design improvement, substitution of improved processes, and substitution of improved materials. Because substitution of materials has been a notable feature of industrial progress, the extremist view is sometimes advanced that all materials are ultimately substitutable and there are no exhaustible resources. This view is difficult to uphold in the face of such examples as the element phosphorous, whose use in agriculture is tied ultimately to the compound adenosine triphosphate which is indispensable for human metabolism. Short of substituting new human beings functioning with entirely new biochemical pathways, there is no substitute for phosphorous.

DATA FOR MODELLING

The inventories of global resources are known, in most cases with useful accuracy. Crustal abundances of the elements, areas of cultivable land, quantities of free carbon available in the fossil fuels and amounts of water precipitation, have been estimated in many instances to within 10 percent and in the worst cases to an order of magnitude. The rate at which difficulty of exploitation increases with the cumulative exploitation is less easily acquired, but for some important examples the analysis is indicative that similar accuracy will be possible. Figure 1 showns the relationship between the cost of inputs per hectare in the warm dry agro-climatic zone and the corresponding yield. These data have been obtained from a series of recent land development projects. The diminishing returns aspect of crop production is expected from the known limits to the efficiency of photo synthesis. The concept of approach to a limit set by physical law is a powerful tool in estimation of likely technical advance, particularly for energy transducers. In the

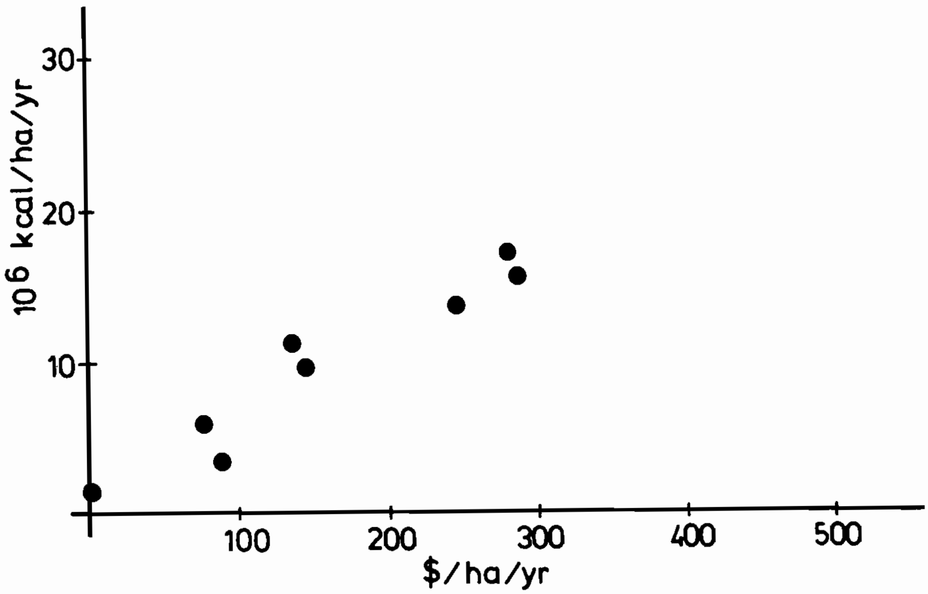

Figure 1. Yield in the WARM DRY agro-climatic zone.

case of large scale hydro-electric installations the fraction of potential energy in the water which is converted to shaft energy of the turbine is already greater than 99 percent for Kaplan turbines. For heat engines the limit is set by the efficiency of the equivalent Carnot cycle, and this is determined by the absolute temperatures reached in the working cycle. Thus, typical modern coal fired power stations reach efficiencies of 35 to 40 percent. Moreover, the rate of approach to the theoretical limit is observed to decline as a function of time. Figure 2 shows the efficiency of fuel burning electric power plants from 1900. This type of curve, sometimes with initially increasing gradient, has been noted in so many cases that a branch of technological forecasting has developed in searching for more exact functional description. Blackman [2] has argued for the use of the logistic and has collected a range of examples to corroborate this choice.

Irrespective of the exact form of the function, it is clear on *a priori* grounds that any figure of merit for any conceivable transducer will show a declining rate of improvement at some point in time. The transducer consists of a particular arragement of atoms and for a finite size of transducer there is a large, but still finite possible number of combinations of varieties of atoms which may constitute the transducer. The vast majority of these possible arragements will have low figures of merit, and a distribution of the numbers of combinations with given figure of merit will show a tail towards the theoretical limit.

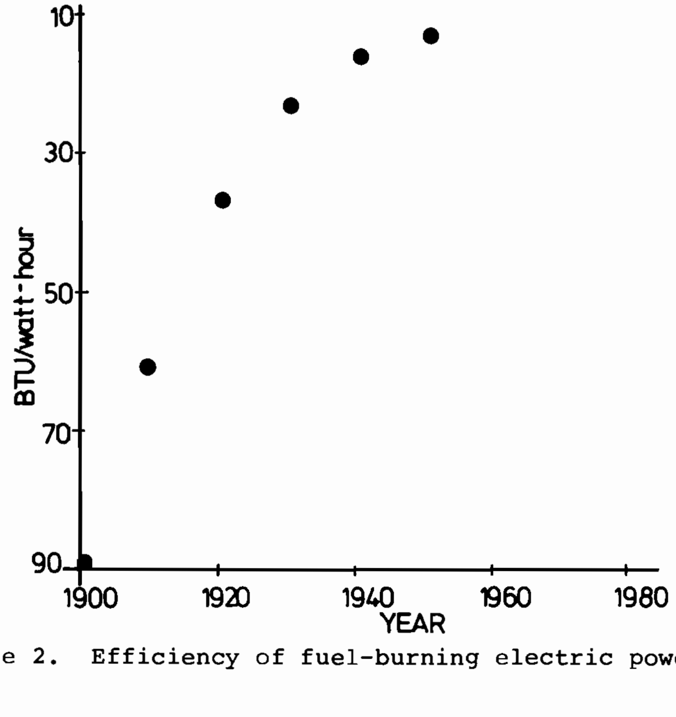

Figure 2. Efficiency of fuel-burning electric power plants.

Each advance into this tail leaves a smaller area in the remainder and hence a diminished probability of discovering a combination with higher figure of merit than that which preceded. The process of search is greatly assisted by the prior knowledge of unsuitable combinations which narrows the choice. This knowledge is formalized in scientific laws and engineering experience. It is closely analogous to the "bound" of a branch and bound algorithm. An attempt to construct an improved transducer is subject to a probability given not by the ratio of the area in the tail to the entire area of the distribution, but to that probability given by ratio of tail area to area cut off by the exclusions derived from current knowledge. Such considerations suggest that in the early stages, when formalized knowledge is advancing rapidly, the figure of merit may show acceleration, but the final approach to a limit will be asymptotic. It also suggests that the advance would be characterized by step changes, particularly in the early stages, when the tail length (possible increment) is comparable with the figure of merit already achieved.

The conclusion which can be drawn is that the forecasting of advances in figures of merit is likely to be accurate enough when the final limit is known from aspects of physical law, and when the current practice is at a figure of merit comparable with that limit. For a large range of conceivable transducers (e.g. growing plants, heat engines, water turbines, photo voltaic solar collectors, nitrogen fixation units), these conditions are fulfilled. However, there are a few notable instances in which the area of uncertainty is large. These are associated with the inputs necessary to contain pollutants to any given specified concentrations. This gap in our knowledge is a severe handicap in the construction of resource models involving much increased output and therefore much increased potential pollutant emissions, particularly carbon dioxide, radio-active waste products and heat.

ASSUMPTIONS

Although the topic of concern is a list of specific physical resources, it is not possible to deal in any depth with the logistic problems unless there are assumptions made about population increase, demand, ownership, distribution and investment. The data necessary for constructing a causal fertility model are poor compared with that available on the inventories of resources and for this reason, it is better to generate scenarios under a range of possible population growth assumptions rather than weaken an otherwise sound model. The least objectional assumption about demand is that the quantities of specific goods and services purchased by consumers are functions of income level. There remain uncertainties about the income and price elasticities of demand but these are not necessarily so great as to obscure the main conclusions of a resources study.

The changes of income distribution observable in different economies throughout this century [3] have been surprisingly small, in spite of the extensive political changes, and the initial assumption of no change in distribution appears reasonable. The sensitivity to possible changes is nevertheless of interest. Changes in the control of resources by individual sovereign states are also very slow, and the assumption of unchanged ownership patterns is similarly acceptable.

The level and apportionment of capital investment is found to be critical in respect of the pressure on resources and this supplies the main raison d'etre for a resource modelling exercise. Investment is affected profoundly by the investors' view of the future. The modelling results that were obtainable from structures aimed at evaluating resource pressure under various investment assumptions are themselves an ingredient in possible pictures of the future. The primary exogeneous variables for a resources model are therefore the determinants of investment.

MODEL STRUCTURE

The interest in resource studies derives from the interactive efforts which are evident in modern societies. A change in the price of energy has a direct effect on the costs of producing nitrogenous fertilizer (which is energy intensive) and this in turn, has repercussions on the cost of food production. It is therefore logical to commence the composition of structure from an input/output basis. The move to a dynamic model can then be accomplished by considering the separate sectors of the input/output matrix as autonomous entities governed by internal optimizing rules of management. The separate sectors are buying inputs of raw materials and labor at the general prices prevailing, and selling output to other sectors and to final demand. For optimal growth, investment should be channelled towards those sectors of high profitability, and it is advantageous to assume such optimal behavior in that the real world, because of the various externalities present, is always suboptimal. Thus the results in terms of resource pressures accord with the best that could happen and the real future is likely to be inferior.

The same a fortiori philosophy is applicable to the interactions between separate economies in that the bargains struck through trade can be assumed for modelling purposes to be the outcome of enlightened self-interest. Aside from the argument presented above for taking this standpoint, there is partial justification for it in the agreement obtainable between time series generated on these assumptions and recorded time series for particular economies.

It is impractical to operate with as many sectors as appear in the input/output tables and with as many economies as there are sovereign states. The levels of aggregation appropriate have been the subject of much discussion and some study [4].

Until more results at different levels have been produced, it will not be possible to speak of optimum degrees of aggregation. The current operation is with 3 strata distinguished by per capita income level, and within that, 10 sectors of production.

RESULTS

All resource problems can be couched in terms of the difficulty of substitution, and models to investigate resource problems are preferably constructed with the mechanisms of substitution in-built to the structure. The sectoral structure is well adapted because the potential substitute can be made the output of a nascent sector whose coefficients are defined but whose production volume is currently negligible. If the cost of the substitute is higher than the original (this is very likely for practical cases), then the market mechanism in the model will cause accelerating switchover to the substitute as the price of the original increases. The nascent sector grows and overtakes its competitor. This process is understandable, observable in the real world and demonstrable in the model. However, the process depends on a price rise for the substituted good caused either by the increasing costs of exploiting a depleting resource or by the owner taking account of the limits on resource availability. The former of these two reasons requires no further examination, but the latter is important because the outcome is directly dependent on the way in which the future is discounted. If it is postulated that a single owner exists for both the original resource and its substitute, then he would rationally invest in substitute production before the original was completely exhausted. This he would do in such a way that continuity of supply was maintained so that the flow of profit from his operation was also maintained. However, the timing of this substitution project is determined by the owner's view of the cash flow sequence which is associated with investment in substitute production. Test runs on this situation show that the resulting scenarios are sensitive to the discounting rate employed to assess the cash flow sequence.

This feature of substitution is not confined to the "single owner" case, nor can it be analysed simply in terms of prevailing commercial interest rates. Consider the growth in requirement for electrical power in the U.K. Assuming the commencement of one 1000 Megawatt nuclear power station each year, a period of five years for completion and a further year before full output is obtainable then the energy accounting figures reveal the following. Energy outflow allowing for load factor is 600 Megawatts and in the earlier years this is entirely used in the energy required for construction of other stations still in the pipeline. Taking into account the energy flows for fuel provision and maintenance, the pay back period is 19.5 years--i.e. there is no net flow of energy for use by the community until this time has passed. Such a program, which can obviously be justified from several different standpoints (ideal of self-sufficiency, known limits to coal and oil reserves etc.), is out of keeping with the commercial rate of return expected on new projects. It is for this reason that the modelling of substitution processes under a range of discount rates is relevant to the study of resources.

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IRADES

Eleonora Barbieri Masini

IRADES (Institute for Futures Research and Education) was founded in 1968 and began functioning in 1969-70, fully aware of the need for studies of the future. Initially, IRADES explored the field to identify who was working in what specific activities of future research, and to select its spheres of interest on a philosophical basis.

Our basic choice, which we could call humanistic, arises from the realization that man--and all men--must change their way of thinking about the future and the rapidly accelerating, interrelated changes that will accompany it. Many global models are being developed and many studies are being carried out. (We are studying the second generation of such models, prepared with great effort, skill and technical equipment.) Therefore, IRADES decided it would educate itself and others toward future thinking as a new way of life, consider the future as always different, and imply choices among alternatives.

The first assumption was that our thinking in the domain of the exact sciences and technology has progressed at a speed that would seem to exceed the limits imposed on man by nature, while our environment (in the broadest sense) has changed; on the other hand, our way of thinking and our political and social behavior are still geared to a pre-industrial state, and our reactions conform to concepts firmly rooted in times that now seem virtually prehistoric. Thus, we must educate ourselves to these new conditions as well as to innumerable others, as yet unforeseen, which will confront us in the future. This is a slow process--education is the slowest of all man's processes--but it must be done with speed if we want to survive.

The second assumption of our work was that if we are to change our way of thinking and prepare ourselves for the future, we must search for qualitative parameters. These are the same parameters which are now preventing us from facing our situation. Are there possibilities for societies based on such parameters interlinked with quantifiable parameters? Our chances for survival lie in the identification of unquantifiable parameters and our capacity to act on them. This is the fundamental question which underlies our efforts to educate; we are working to develop these as a basis for responsible choices for alternative societies.

Thus, IRADES is working to prepare men's minds to receive the results achieved by these studies and to react to the sort of work presented here at this conference, in short to prepare and to act for the future. This education--what we call education toward the future--is directed toward three specific categories:

a) Policy-Makers. In this endeavor, we publish books and studies prepared by the Institute or by others, and hold workshops, led by specialists, to relate the possibilities of future studies with policy-making;

b) Young graduates beginning new careers. We seek to orient their new professions toward the future. This we shall do through our new school of future studies, opening in two weeks--the first such school in Italy and one of the first in Europe. This school will explain and discuss the various world philosophies of future studies, and basic methods, illustrated by such exercises as scenario building, the application of Delphi methods, etc., in which the students will participate actively to develop their individual creativity;

c) Public opinion. This we hope to reach by publications, meetings, conferences, television programs, and so forth.

This educational work is founded on the research and study carried out by a group of 10 professionals from various disciplines, in the process of developing what we call the basic subjects of our educational program. These are:

- Philosophies on which futures studies are based in various parts of the world, and their applications;

- Methods of future studies and their application in various institutes (IRADES applies alternative scenarios for Italy and for Europe as well as Delphi methods for Italian problems);

- Human needs and value changes on the global level; and

- Impact of social communication on education towards the future.

In conclusion, we are not working in global modeling but rather trying to prepare individuals mentally to receive, accept, reject and choose among models of future life that will confront them. Life models must be chosen and acted upon; we must not merely subject ourselves to them. Some may think our goal is utopian, but I believe that we need more utopias that can be realized.

Reallocation of the World Industry

Y. Kaya and M. Ishikawa

INTRODUCTION

It is hardly an exaggeration to say that alleviating the poverty of the vast numbers of people living in the developing nations is the greatest world problem we face today. While the U.S.A., Japan, and the countries of Western Europe have advanced to a civilization enjoying a GNP of several thousand dollars per person, the developing nations have a per capita GNP of less than $200 a year; chronic malnutrition and hidden unemployment are rampant.

To promote development and reduce this great gap between the northern and southern nations, various efforts, usually in the form of economic aid, have been made. Even considering the significant aid given so far, we must admit that it has not effectively achieved its purpose. The economic growth rate of the developing nations shows only a weak statistical correlation with the quantities of aid which have been received.

Development Based on Agriculture and Mining is Not Sound

Historically, most of the advanced nations developed themselves without relying on any special aid from outside. In the light of this experience, it is natural to look to the developing nations to follow this same path without being overly dependent on economic aid. It is precisely to discover concrete ways in which this might be done that we have undertaken this study.

One way to approach this problem of self-development would be to encourage the poorer nations to expand their agricultural and mining industries. In the past, their exports have been principally mining and agricultural products; furthermore, most of the developing nations lie in the tropics where they are blessed with a warm, moist climate conducive to agriculture.

This approach has two weak points. The first comes from a mistakenly exaggerated idea of the richness of the natural resources in the developing nations. In Table 1 we have listed figures for arable land, petroleum and uranium reserves for the various regions of the world. Asia with over one half of the world's population is poor in land and resources. Africa and South America seem to have a considerable amount of potentially arable land, but much of the soil is of the type found in the tropics. This type of soil lacks the ability to store organic nutrients, and so, with present agricultural technology, cannot

Table 1. Natural resources of the world by regions.

Region	(1969) Population (millions)	(1966) Per capita income (U.S.$)	Land area per capita (hectares)		Energy resources per capita	
			Arable land	Potentially arable land (not yet under cultivation)	Absolute existing amount of petroleum (100 tons of coal equivalent)	Absolute existing amount of uranium (U_3O_8) (Kg.)
North America	220	3800	1.1	2.1	15.6	3.2
Central & South America	310	430	0.32	2.3	8.9	
Western Europe	460	1700	0.33	0.37	1.5	0.4
Soviet Union & Eastern Europe	240	1500	0.93	1.46	3.8	0.6
Asia	1,810	200	0.28	0.34	0.2	
Africa	340	160	0.46	2.1	6.8	0.2
Australia & New Zealand	20	1770	0.8	7.6	2.1	2.0
Middle & Near East	40	370			26.6	

Notes:

(1) Based on Hopper's assumption that only 30 percent can be used.

(2) Quality of ore valued at $10/ton or more in 1972.

(3) Based principally on data from The World Food Problem, United States Government Printing Office, 1970.

be made nearly as productive as the soil in the temperate zones of the world.[1]

In the developed regions such as North America, Oceania, and the Soviet Union, and Eastern Europe, both rich soil and mineral resources exist in such abundance that they should be called "resource countries." It is now possible for the developing countries to export mining and agricultural products because their domestic consumption is extremely small. Even if the export pattern of the developing countries were to be accepted now while their living standard is still low, it cannot be continued as they develop, because domestic consumption will begin to take up the entire product and make export more difficult. If development should be based on this export, the development itself will be stopped.

The second point is that agricultural products will not maintain their income elasticity throughout the period of development. Since agricultural products are so basic to human life, their income elasticity is now very large in the developing nations. As incomes increase, the demand for agricultural products, which are mostly raw foodstuff, does not expand very much, and so the economic elasticity of these products decreases. If we compare, for example, the demand for agricultural products in the U.S.A. and in India, we find that the demand is only six times as great in the U.S.A. although the per capita GNP is 40 times as great. Without a large increase in demand for agriculture products, an economy based on agriculture simply cannot grow substantially.

Manufacturing Industry: Its Need and Some Problems

In view of what we pointed out above, one can see that the development of manufacturing industry is indispensable. Fundamentally speaking, the most desirable way to pursue development would be to import raw mineral resources, manufacture products which can be produced anywhere, but which have a high income elasticity that does not fall off as the per capita income increases. In the past almost all of the present advanced nations have reached what Rostow has called the economic "takeoff point" by rapidly expanding their manufacturing industry. In the countries of Asia, although agriculture is recognized as the basic industry, they still have not a great desire to expand their manufacturing industry.

There are a number of obstacles to the development of manufacturing such as the lack of domestic capital and the lack of technical know-how. In the long run, however, an even greater

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[1] In the "burnt-field" type of farming, the field must be left fallow for six to twelve years after being used for only three or four years. Otherwise, the organic nutrients in the soil will be exhausted.

obstacle will be the difficulty of securing adequate markets for the manufactured products. Up till now, all the world markets for manufactured goods have been dominated by the advanced nations, a situation that is expected to continue as long as manufacturing is their central economic activity. If, under these conditions, the developing nations should advance somewhat in manufacturing, they must invade the markets of the advanced nations and enter into head-on competition with them. It is difficult to imagine that the developing nations would be able to expand their industry to such an extent that they would be able to compete successfully with the advanced nations. No matter how one looks at it, from the standpoint of supply and demand, unless the advanced nations change the pattern of exporting their manufactured goods, the developing nations will always remain importers of such goods and never be able to develop their own manufacturing industry to any great extent.

Need for a Plan to Re-distribute the World's Manufacturing Industries

Since, over the long run, the greatest obstacle to the economic growth of the developing nations will be their inability to secure markets for their products, we must attack this problem. One way would be to accelerate the economic growth rate of the advanced nations in order to increase the demand for the mining and agricultural products exported from the developing nations. This policy would be only a stopgap, though, for the developing nations are not so rich in natural resources, nor would the demand for imported agricultural products increase much in the advanced nations. An even greater drawback to such a policy would be that the earth's resources could be used up at an even faster pace, and more pollution would be thrown off by ever-accelerating manufacturing in the advanced nations. From a global point of view, the most desirable policy is one that will help the developing nations to grow while restraining the global economic growth rate.

How, then, can we accelerate the development of the underdeveloped, while at the same time not accelerating the economic growth rate of the developed nations? More abundant economic aid might be given, but this will hardly solve the problem as long as the developing nations cannot obtain markets within the advanced nations. By giving economic aid, the advanced nations would have to reduce their demand for investment goods and thereby reduce the markets available to developing countries. Also since manufacturing requires an able labor force and technical abilities, large inputs of economic aid cannot produce results in a country where these requisites are not yet found.

The most effective solution would be for the advanced nations to modify their own industrial structure so as to create markets throughout the world for the products of the developing nations. The advanced nations could give up manufacturing some products which could then be made in the developing nations. In the advanced nations, knowledge-intensive and agricultural industries could be further developed to make up for the industries given up. This type of policy would certainly help the developing nations effectively.

To foresee in detail just how the industrial structure of each nation should be changed to achieve the above effect is not an easy problem. In each country, for example, the natural resources, the land, labor force, amount of capital, and market demand are all influenced by physical and economic factors; furthermore, these factors are constantly changing. Also, looked at from a global viewpoint, if the supply and demand for a certain type of goods gets out of balance, political and economic instability may result. Consequently, production must be carried out in the various countries of the world in such a way that year by year the balance of supply and demand is maintained.

We have taken up this problem using a regionally-sectored dynamic world model. By optimizing the behavior of the model a desirable pattern for the re-distribution of the world's industries was worked out and various aspects of the solution were investigated.

The plan developed here, referred to as "World Industry Redistribution Plan," is a kind of "international division of labor." Ever since Ricardo first proposed it, such an international division of labor has always been viewed primarily as a means of increasing productivity. Our plan, however, is quite different in that it aims at the development and increased productivity of the developing nations.[2] Of course, the plan is an ideal which cannot be realized without overcoming many international political obstacles. This direction is nevertheless the most effective way to help the developing nations, and we hope that the advanced nations will realize this and begin to make efforts to re-structure their industry to this purpose.

The model we have built is not yet perfected; also the data that we have used so far must be checked over and improved. The scope of the problem that this model is intended to solve is too large and complex for one group of private researchers. Therefore, we hope that the work will be made a project of some international organization such as the United Nations or the Organisation for Economic Cooperation and Development (OECD). We believe that the methodology and the results we present here could be made the basis for effectively pursuing this as a large project.

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[2]Although other economic models have used mathematical programming, as far as the authors know, theirs is the first to attempt a dynamic simulation of a distribution by regions and economic sectors.

THE METHOD USED TO TEST OUR PLAN

To study this plan in greater detail and from many aspects we have built a world industry model which has individual subsystems for each geographical region and for each sector of industry in each region. Here we will give only a simple outline of our method; the details of the mathematical formulation and method can be found in the appendix.

The Parts of the Model

The world was subdivided into nine regions, and in each region six industrial sectors were considered.

The regions are: North America, Oceania (Australia and New Zealand), Western Europe, Japan, Soviet Union and Eastern Europe, Central and South America, Asia (excluding Japan and China), Africa, and China.

The six industrial sectors are: agriculture, mining, light manufacturing, heavy manufacturing, assembly (knowledge-intensive) manufacturing, and service industry.

For each region there are models for industrial production, potential demand, and population. The behavior of these interacting models is controlled by investment according to region and industrial sector. These investment inputs are devised to minimize a cost function which will be explained below. The basic structure of the model is shown in Figure 2.1.

The Factors Included in the Cost Function

There are four factors each of which influences the value of the cost function.

1) The production-gap factor. This factor is designed to become smaller for a particular region as the total per capita production increases. Therefore, using investment to decrease the cost function with respect to this factor tends to raise the industrial output of the regions with a low gross regional product (GRP).

2) The supply-demand imbalance factor. This factor is a sum of the squares of the global differences in supply and demand within each industrial sector. When this factor is small it means that, supposing an ideal form of international trade, the supply and demand in each industrial sector is well balanced. By inserting this factor, we assure that the re-distribution of industry obtained by our model will not fail to meet this most basic requirement for a realistic solution. These are the two principal factors in the cost function, but we also add other factors as required for studying particcular aspects of the problem.

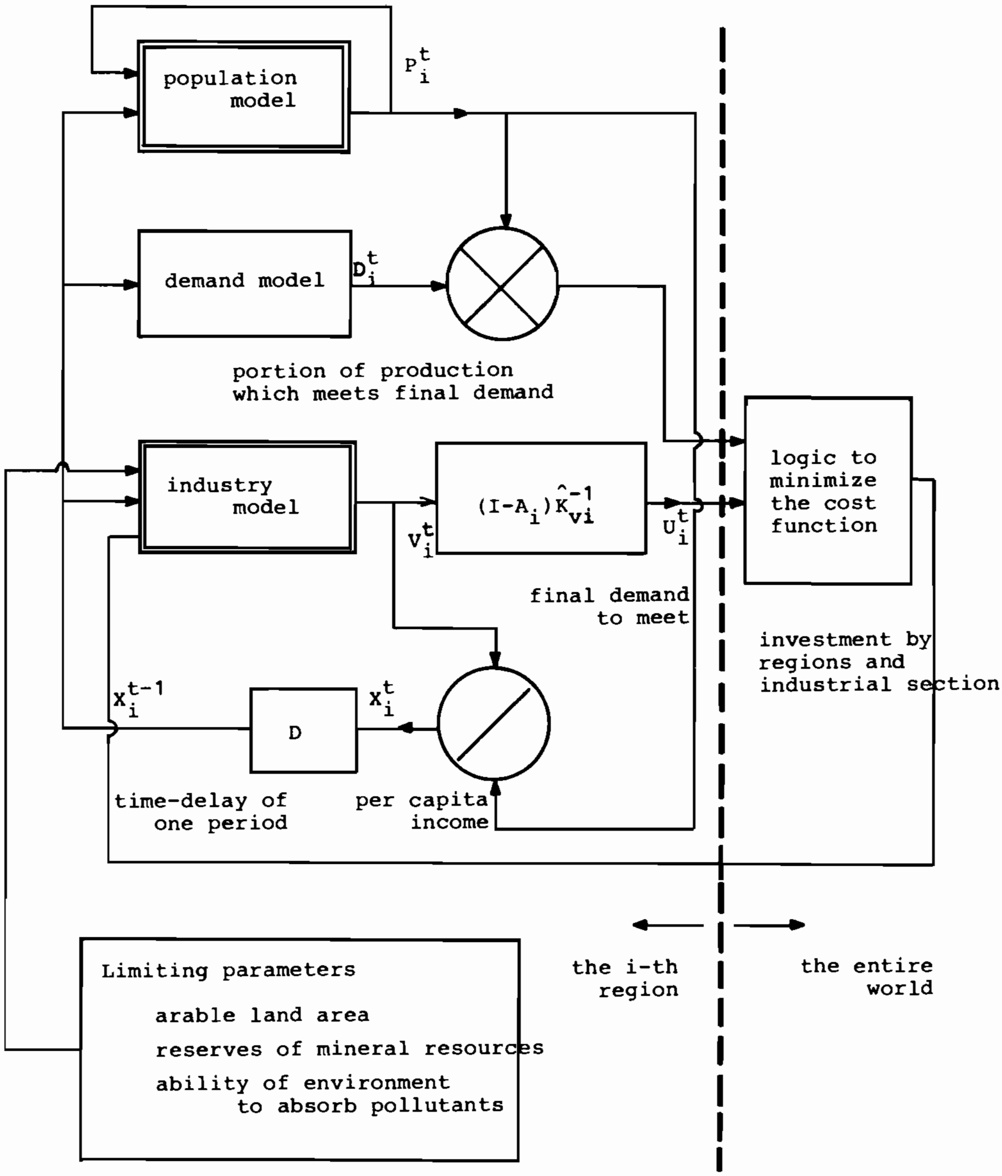

Figure 2.1. Basic structure of the model.

3) The economic self-sufficiency factor. The degree in which a region supplies its own demands in a particular industrial sector is the degree of its economic self-sufficiency. By incorporating this factor into the cost function, we are, in effect, recognizing that for the security of a region and for the reduction of freight transportation from region to region, each region requires a certain degree of such self-sufficiency.

4) Energy pollution factor. This is a factor related to the energy consumption per unit of surface area in each region. We use this factor in the cost function when we want to ensure that the model will produce a solution in which the regional environments will not be unequally burdened by pollutants from energy consumption.

Capital Coefficients for Each Region and Industrial Sector

The industry model for each region takes into account the relations among the six industrial sectors. For simplicity, we have adopted the simple relation defined by:

$$\text{(increment in value added)} = \frac{\text{(investment)}}{\text{(marginal capital coefficient)}} \quad (2.1)$$

The marginal capital coefficients for each of the sectors were based on data for past years. The coefficients used for the three manufacturing sectors are shown in Figure 2.2. In a region, when the income level rises, then, in general, the level of knowledge and manufacturing ability also rise. This fact is reflected in the way the coefficients in Figure 2.2 slope down to the right. A more complete explanation of our way of setting the marginal capital coefficients can be found the appendix. At this point, it is also good to note that the capital coefficient for light manufacturing is the smallest of the three sectors, and the highest is for assembly manufacturing.

For the agricultural sector we made separate models for the agricultural use of land already under cultivation and for the land just being brought under cultivation. In each of the regions, these agricultural models take into account the differences in arable land area as well as the fertility of the soil.

In the mining sector we considered petroleum as the representative product upon which we based the structure of the model. Compared to other sectors, the mining sector exerts so little economic influence that it has little effect on the overall behavior of the model.

In each of the regions we divided the potential demand into that for consumption goods and that for investment capital. The

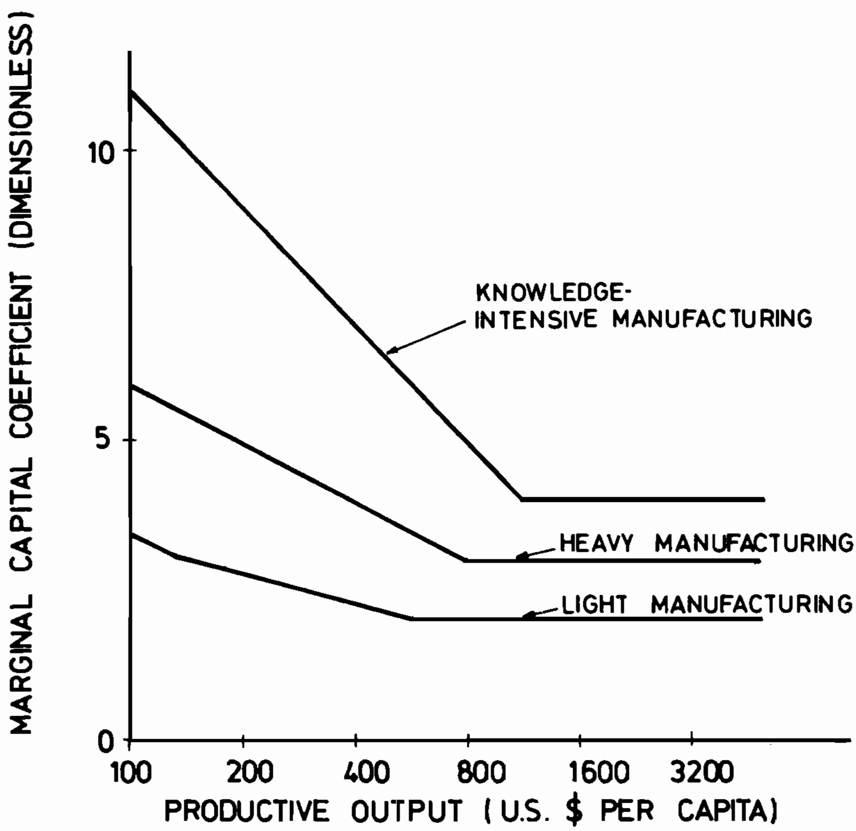

Figure 2.2. Assumed marginal coefficients for the three manufacturing sectors.

demand for consumption goods was set up as a function of gross regional product (GRP); data for the past years in Japan was used to determine the exact functional relation. The demand for investment capital, taken merely as an overall investment ratio, was also set up as a function of per capita GRP.

The population model we are using does not take into account the age structure of the population, but works according to the simple formula:

$$\text{(increment in population)} = \text{(crude birth rate)} - \text{(crude death rate)} \times \text{(total population)} \qquad (2.2)$$

Here we set up the crude birth rate and the crude death rate as functions of per capita GNP, using data for past years to determine the exact form of the relation.

The Control Variables

Annual investment by region and industrial sector constitute the control variables in our model. One exception to this is the service sector investment which we connected to the per capita GNP of the region, since there is very little export of service to meet demands in other regions. In the mining sector also, we made a special provision so that the investment in this sector would always be enough to supply the other sectors with the necessary raw materials for production. For all of the investment variables we imposed the following restraints:

$$\text{(amount invested)} \geq 0 \qquad (2.3)$$

$$\text{(overall amount invested)} = \text{(overall investment rate)} \times \text{(GNP)} \qquad (2.4)$$

The Future Period Simulated

Since new developments in technology and their effects are difficult to predict, we do not think that our model can give meaningful results for any more than forty years into the future, and so we restricted our studies to the period from 1970 to 2010 A.D.

The Method of Optimizing the Solution

If one seeks to minimize the cost function at each one-year interval, the problem can be set up to apply quadratic programming to the search for the best investment pattern. In this report, all of the results presented were obtained in this way.

Another approach to the problem would be to look for an investment pattern which minimizes the cumulative value, that is the integral of the cost function over a period of years. Then, instead of optimizing at one-year intervals, the problem becomes one of optimizing the dynamic performance of a large, nonlinear system. For this, the necessary computation is immense. We did, however, try this approach for a few cases; fortunately, we found that the results were not much different from those obtained by optimizing at one-year intervals. We think that this close agreement is probably owing to the scarcity of time-delay elements in our model, but we intend to do further work on this dynamic optimization.

USING THE MODEL TO EVALUATE THE INDUSTRY RE-DISTRIBUTION PLAN

Ability of the Model to Compare Policies

Using the techniques outlined in the previous section, we made simulation runs to examine the effect of the industry re-distribution plan. It is difficult, for a 40-year period in the future, to determine the correct values of the various parameters which affect the behavior of the model. Consequently, it would be rash to give too much credence to the absolute numerical results the model produces. The model can be used effectively to compare the results of different approaches to the problem. We have compared, for example, the results obtained when increased productivity is made the sole criterion for the optimum re-distribution of industry. Such a run with the model we have called a "productivity-oriented run"; in the model, it represents a policy similar to that proposed in Ricardo's "international division of labor" theory. In terms of the cost function explained in the previous section, this run is carried out by making only one change: the production-gap factor is omitted from the cost function. In contrast to this result, the plan we propose is simulated by the model in what we call the "development-oriented run."

Industry Re-Distribution: The Resulting Pattern and Its Effect

First let us see what effect re-distribution of industry has on the developing regions. Of course, the relative numerical importance we give to the production-gap factor in the cost function will affect the result, but in Figure 2.3 we show one typical result. The figure displays, for comparison, the result obtained by the production-oriented run (solid line) together with that obtained for the development-oriented run (dotted line).

As one can see from Figure 2.3, the results of the two policies are about the same until after 1980 when a clear difference appears. The development-oriented run clearly decelerates the growth rate of the advanced regions and accelerates that of the developing regions. Thus, even though the growth rate of the developing regions is much higher than in the productivity-oriented

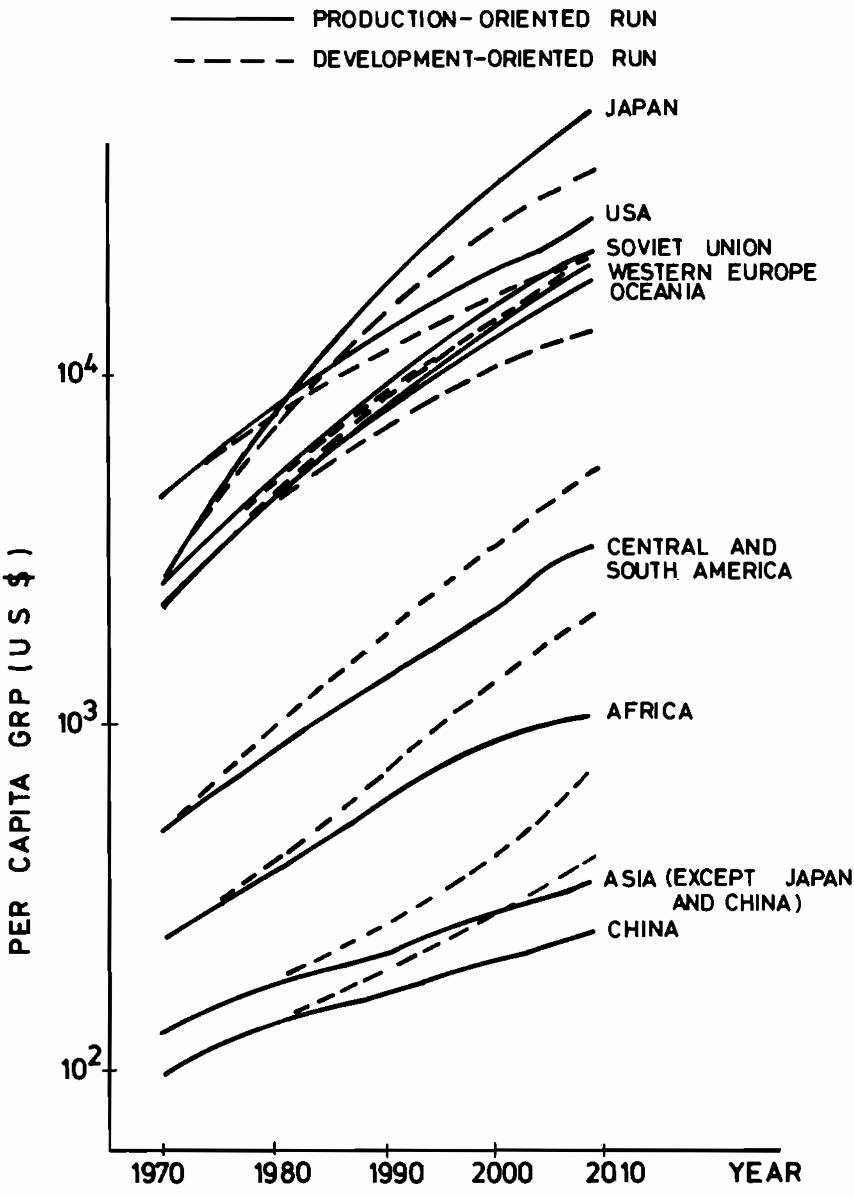

Figure 2.3. Comparison of production-oriented and development-oriented simulation results, per capita GRP.

run, the global economic growth rate is still less than in the productivity-oriented run. This conforms to the requirement of Section 2.1: "From a global point of view, the most desirable policy is one that will help the developing nations to grow while restraining the global economic growth rate."

For these same runs we can examine the resulting industry re-distribution patterns. Figures 2.4 (1) to (9) show these patterns region by region. The graphs show only the relative contribution of each of the six sectors to the gross regional product (GRP). One should be careful to note that, even though the relative contribution of a sector drops in the future, this does not by any means indicate that the gross product of that sector has decreased; it only indicates a drop relative to other sectors in that same region. If we look at North America in Figure 2.4 (1) we see that the development-oriented run differs little from the productivity-oriented run in the beginning, but later the share of the GRP owing to agriculture increases while that owing to light manufacturing decreases. By contrast, in Asia, as can be seen in Figure 2.4 (7), agriculture increases its importance very rapidly in the beginning of the development-oriented run owing to the initially high income elasticity from rapidly increasing demand and to the high capital efficiency attained by labor-intensive agriculture. But as development advances, the portion of the GRP owing to agriculture drops considerably and that owing to light manufacturing grows very large.

The reason for these changes in the agricultural sectors of North America and Asia is not hard to find. North America has, on a per capita basis, very abundant farmland having a high productivity. In Asia, on the other hand, agriculture develops initially, but then the capital efficiency drops because of the shortage of land, and so the economically more promising light-manufacturing sector expands very much. In North America also, the capital efficiency of agriculture is less than that of light manufacturing, and so the expansion of agriculture there accompanied by a decreasing share of the GRP from light manufacturing means that the economic growth rate is decreased.

One could object, pointing out that progress in agricultural technology will undoubtedly raise the productivity and the capital efficiency of the scarce farmland of Asia. With such progress, the objection would run, would not the structure of industry in Asia be quite different from that obtained here?

To investigate this point with the model we made a run in which we now incorporated a 2 percent annual increase in agricultural productivity. This figure of 2 percent is, we believe, on the optimistic side, since the FAO goal of a global 3 percent increase in total agricultural production, which also includes the yield from land newly brought under cultivation, has not yet been attained. The results of this run are, for comparison, plotted together with those of the previous run in Figure 2.5.

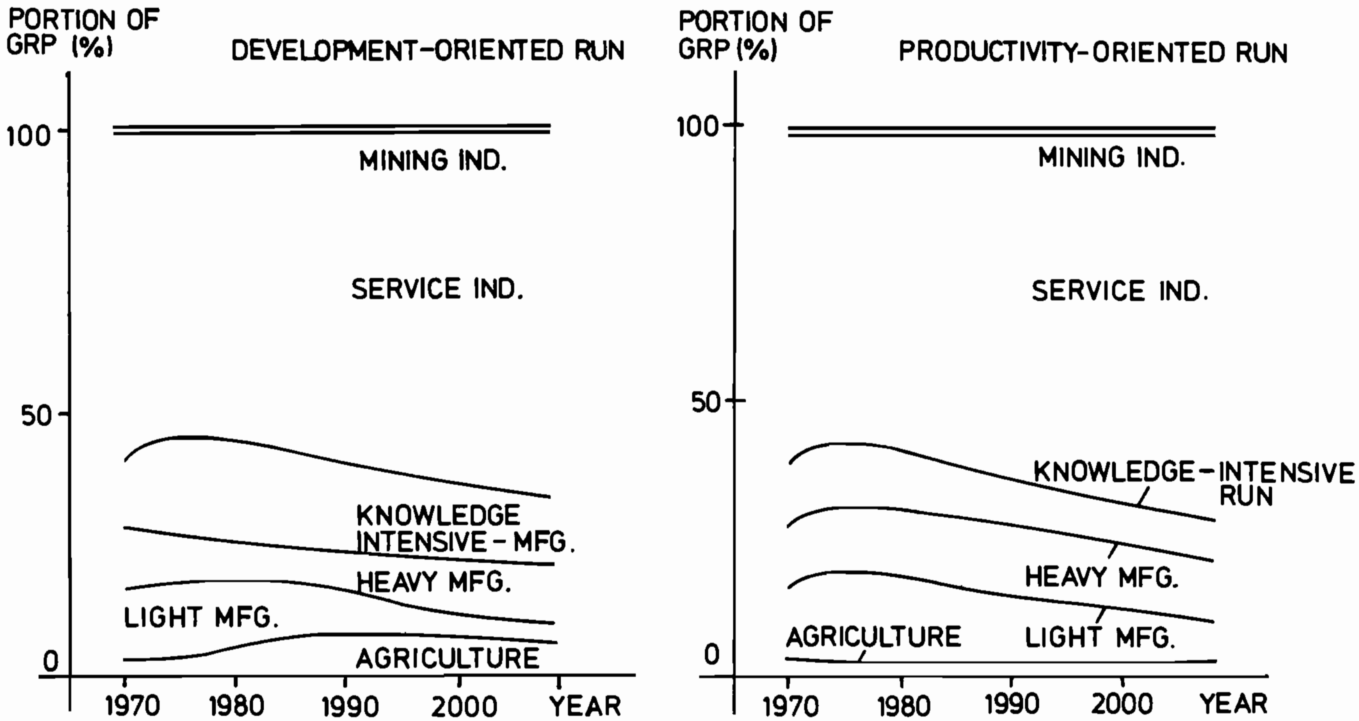

Figure 2.4 (1). Structure of the GRP for North America.

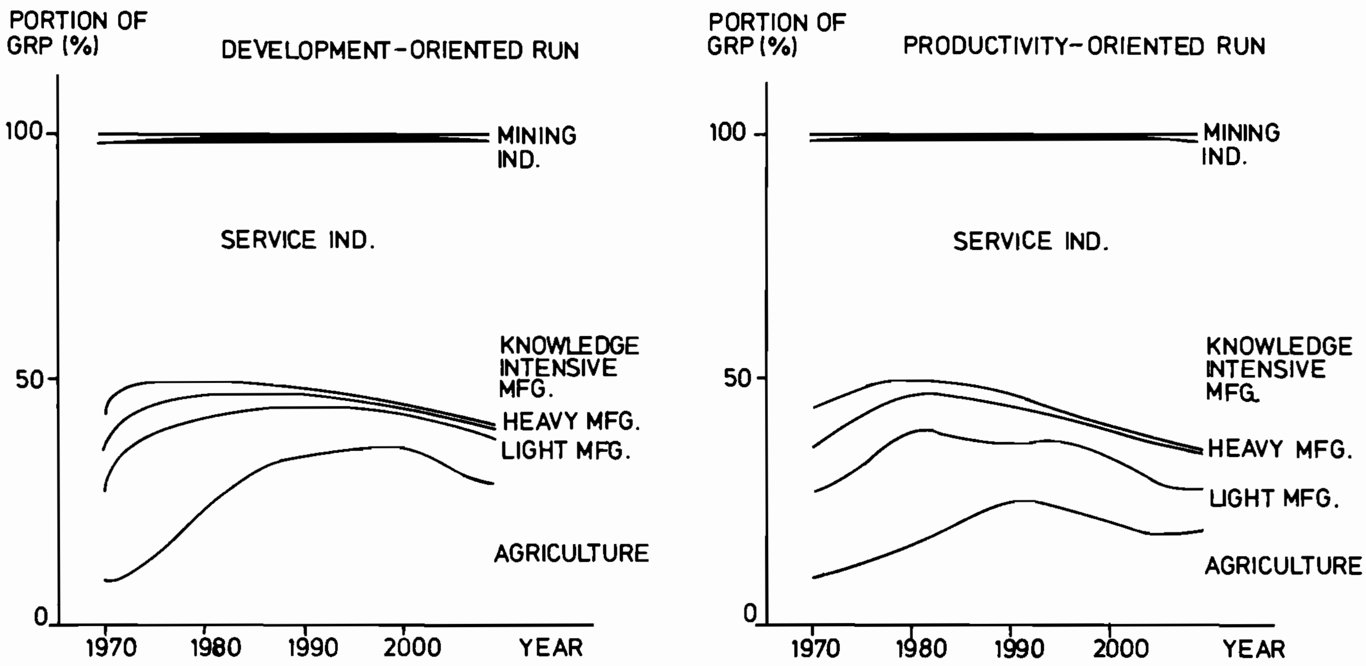

Figure 2.4 (2). Structure of the GRP for Oceania.

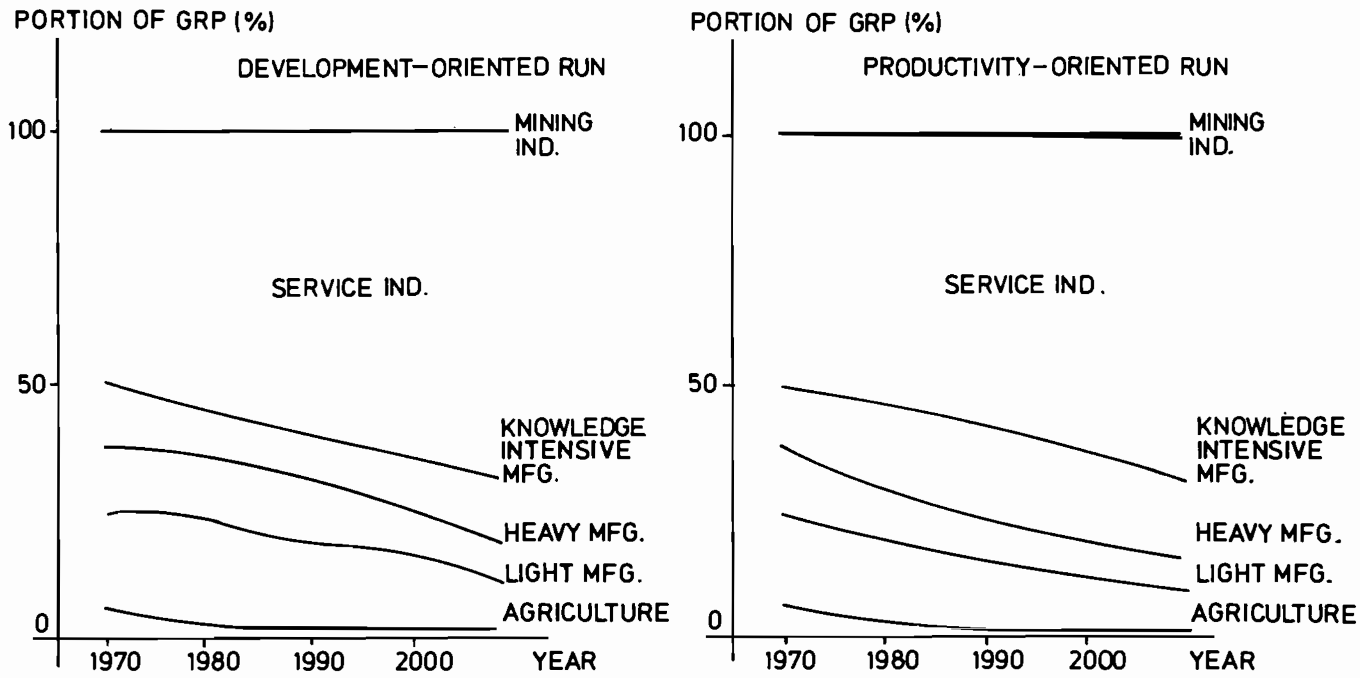

Figure 2.4 (3). Structure of the GRP for Western Europe.

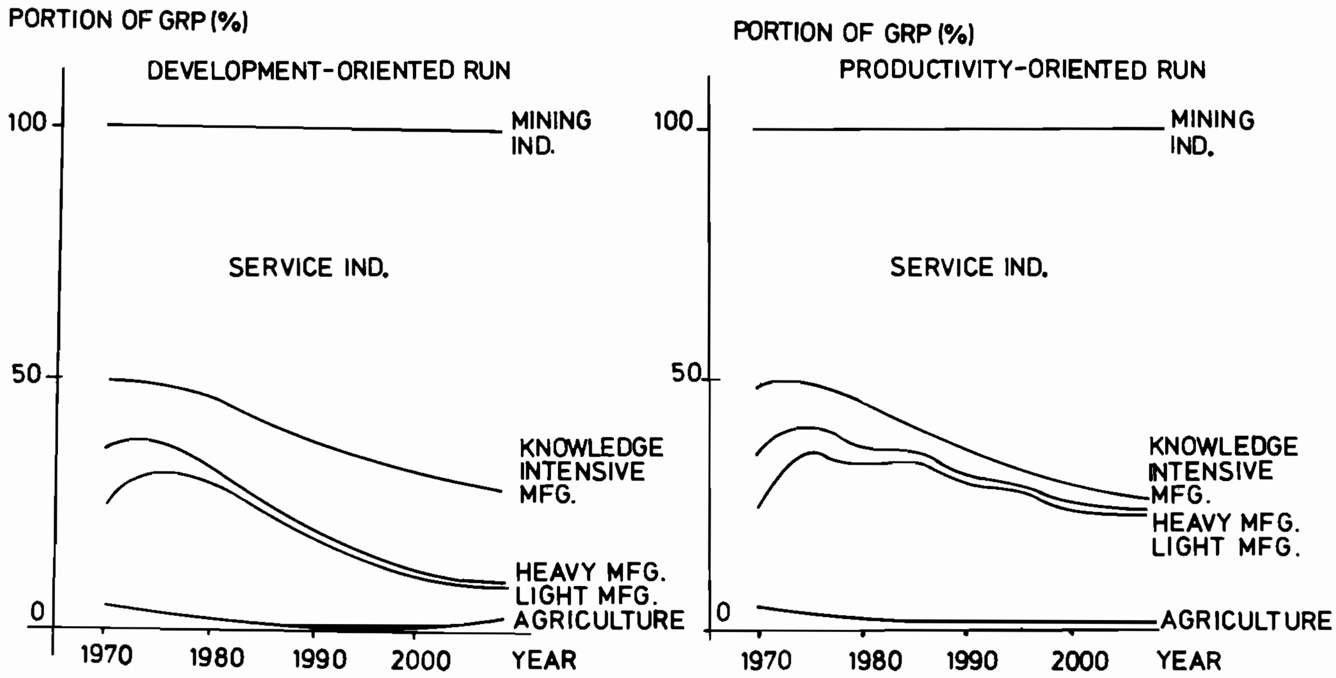

Figure 2.4 (4). Structure of the GRP for Japan.

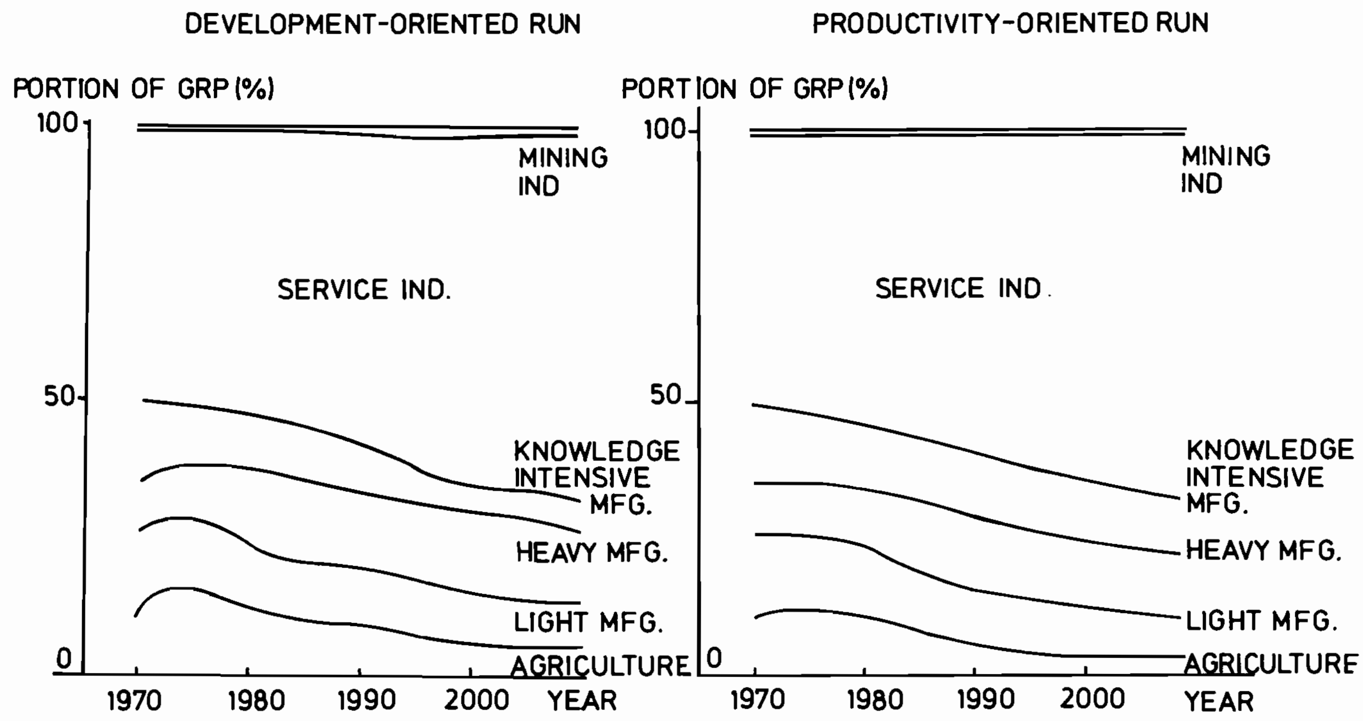

Figure 2.4 (5). Structure of the GRP for U.S.S.R. and Eastern Europe.

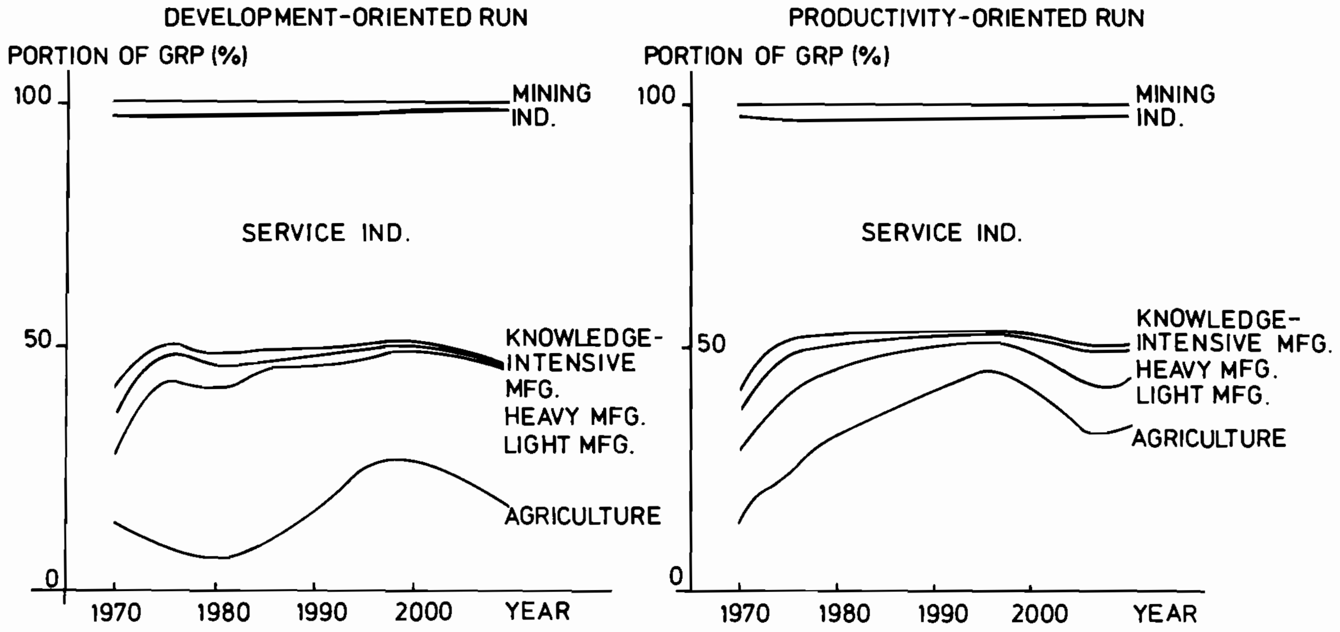

Figure 2.4 (6). Structure of the GRP for Central and South America.

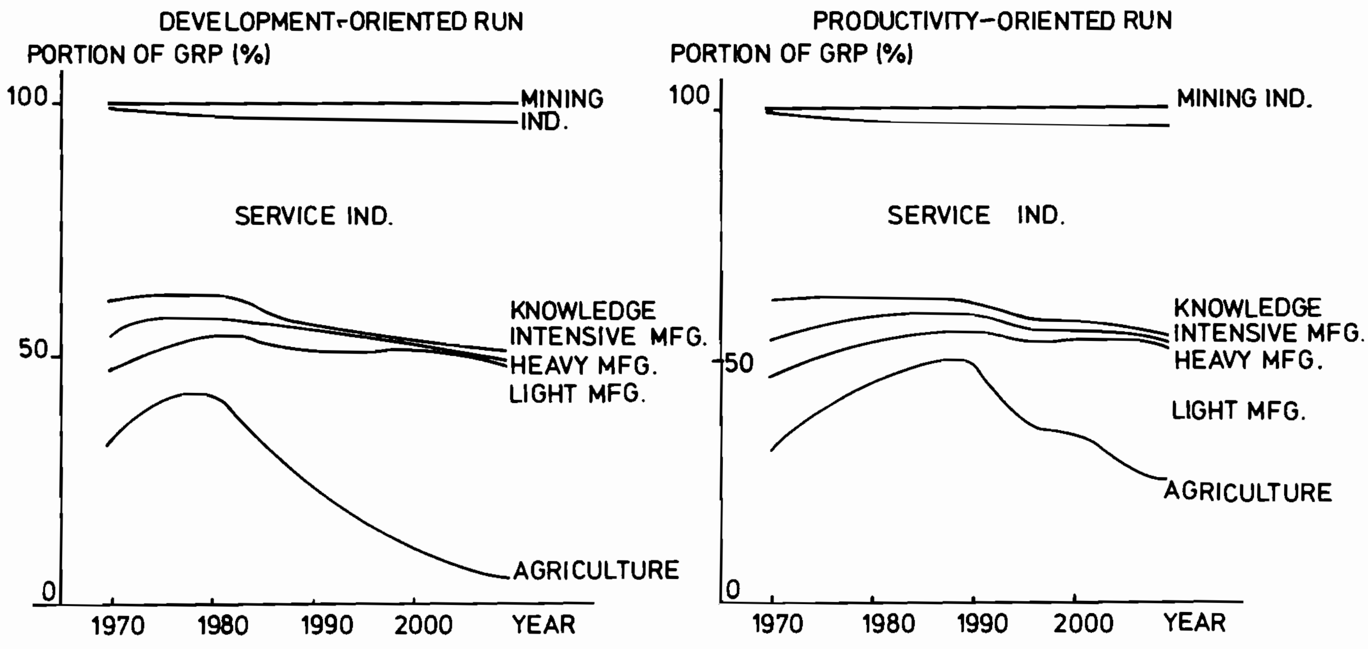

Figure 2.4 (7). Structure of the GRP for Asia (excluding Japan and China).

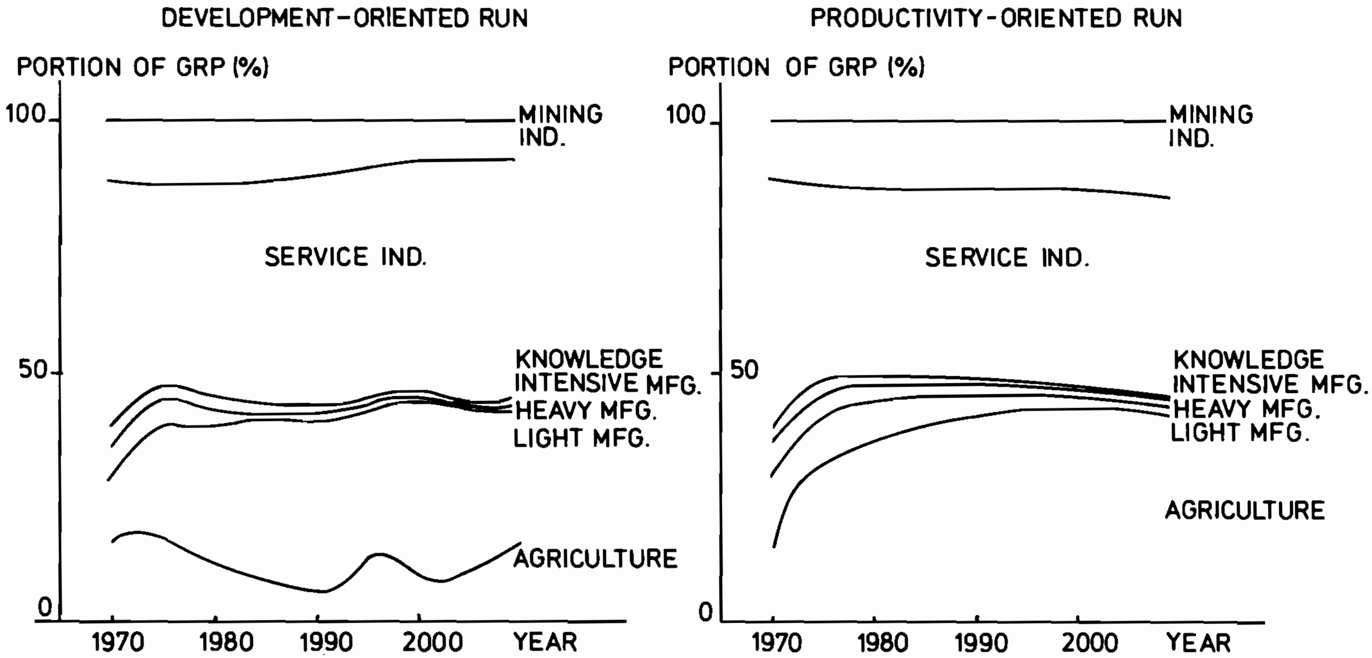

Figure 2.4 (8). Structure of the GRP for Africa.

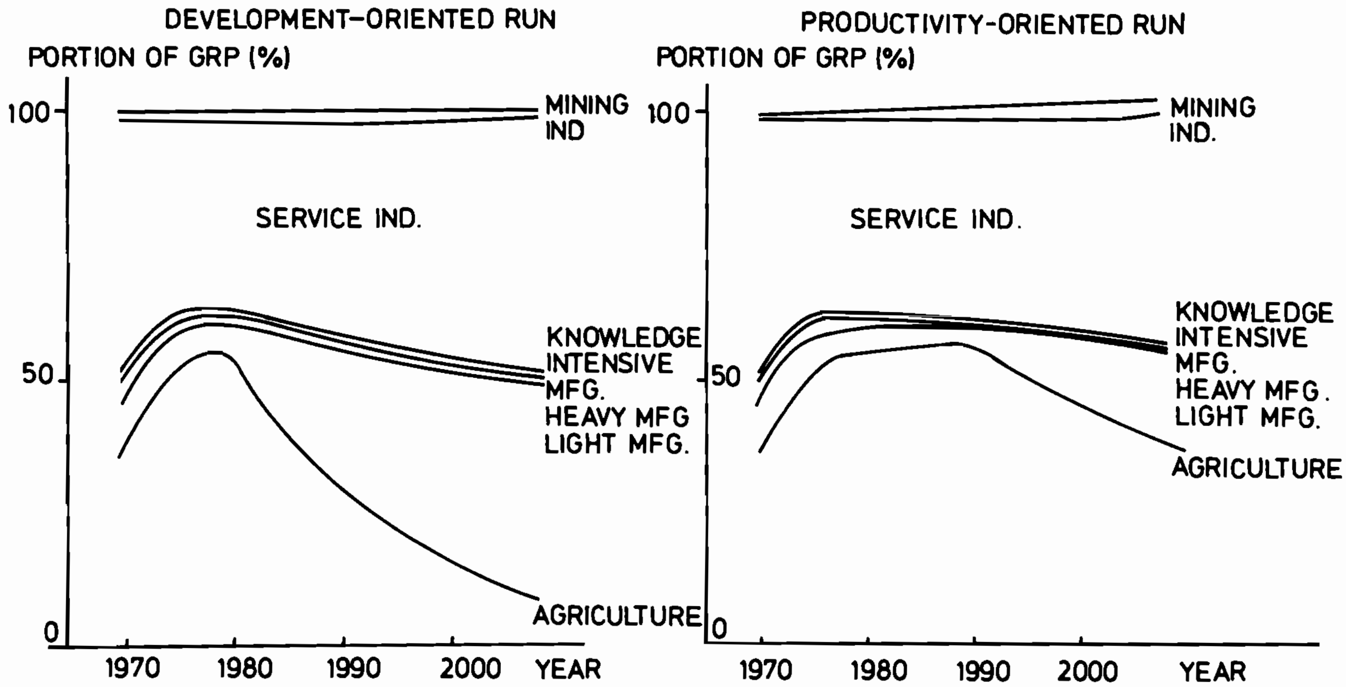

Figure 2.4 (9). Structure of the GRP for China.

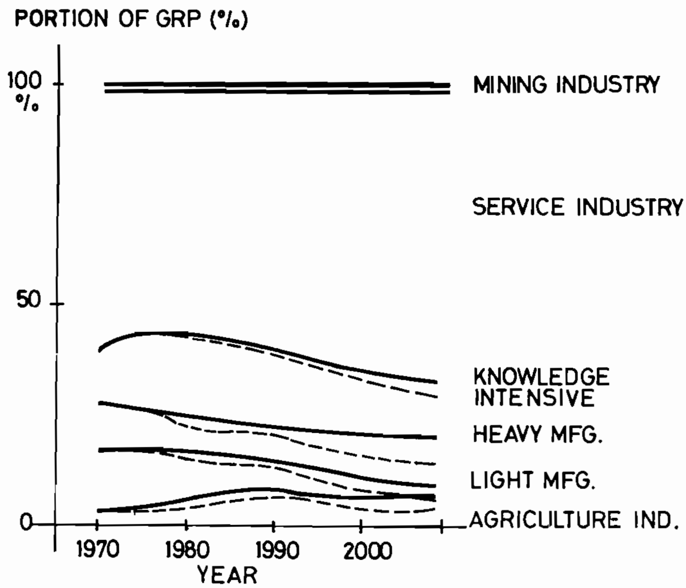

Figure 2.5 (1). Influence of improved agricultural technology on the structure of the GRP in the USA.

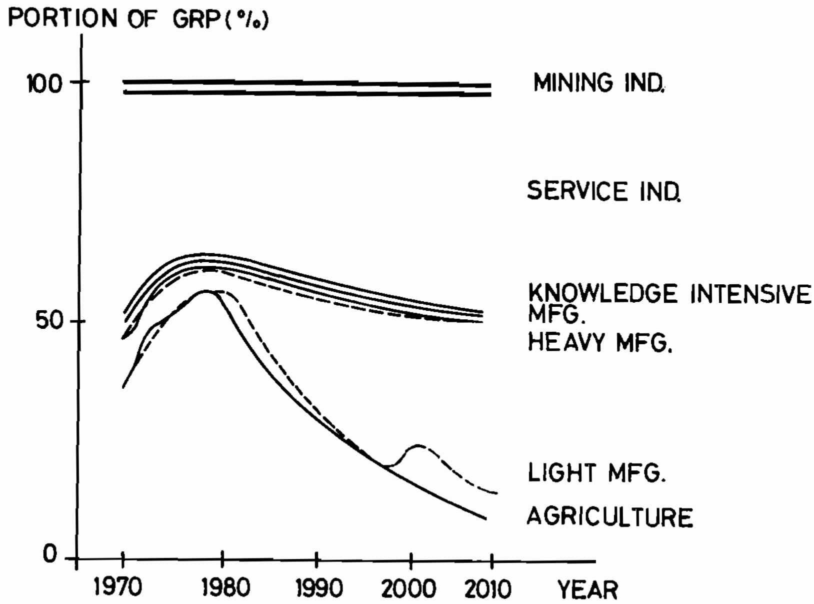

Figure 2.5 (2). Influence of improved agricultural technology on the structure of the GRP in Asia.

The results in the agricultural sector of North America and of Asia show the tendency one might expect. The relative contribution of agriculture in Asia is increased; that in North America is decreased. The model, however, does tell us that this assumed improvement in agricultural productivity does not affect much the optimum pattern for the distribution of industry.

Not only in this experiment, but also in a number of other cases we examined, the model always gives results similar to the above: in North America and Oceania, agriculture expands its weight in the GRP; in Asia, this sector decreases in importance while light manufacturing expands.

Bad Effects of a Policy of Regional Self-Sufficiency

Obviously, if a region can more or less supply its own demands, the nations there enjoy greater security. But if economic self-sufficiency should be overly emphasized, then only the regions with adequate natural resources would actually attain this goal. Such a policy is clearly opposed to the principle of our plan, namely that of seeking an international division of industry to promote the economic productivity of the developing nations.

Using our model, we investigated the bad effect that would result from a certain degree of emphasis on regional self-sufficiency. Since, in the mining sector, there are some regions for which self-sufficiency is impossible, we did not include this sector in the experiment. Nor did we consider the service sector, since service is of its very nature supplied in a self-sufficient manner in each region. In Figure 2.6 we show the results obtained for the year 2010 when three different degrees of self-sufficiency are incorporated into the model. Case 1 gives no emphasis to self-sufficiency; Case 2 supposes a degree of self-sufficiency about equal to that operative in the world economy today; Case 3 emphasizes self-sufficiency the most, considerably more than in the actual world economy today.

To evaluate the results we used an index which indicates the degree to which self-sufficiency has not been attained. This index could be called the "index of dependence."[3] The "average

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[3]The index of dependence for each industrial sector in a given region is defined as:

$$(\text{index of dependence}) = \frac{\text{total demand for product}}{\text{total production of product}} - 1$$

The "average index of dependence" for a region is the average of the indices of dependence for four industry sectors of that region, namely, agriculture and light, heavy, and assembly manufacturing. Consequently, a small value of this index indicates that the region has a high degree of self-sufficiency.

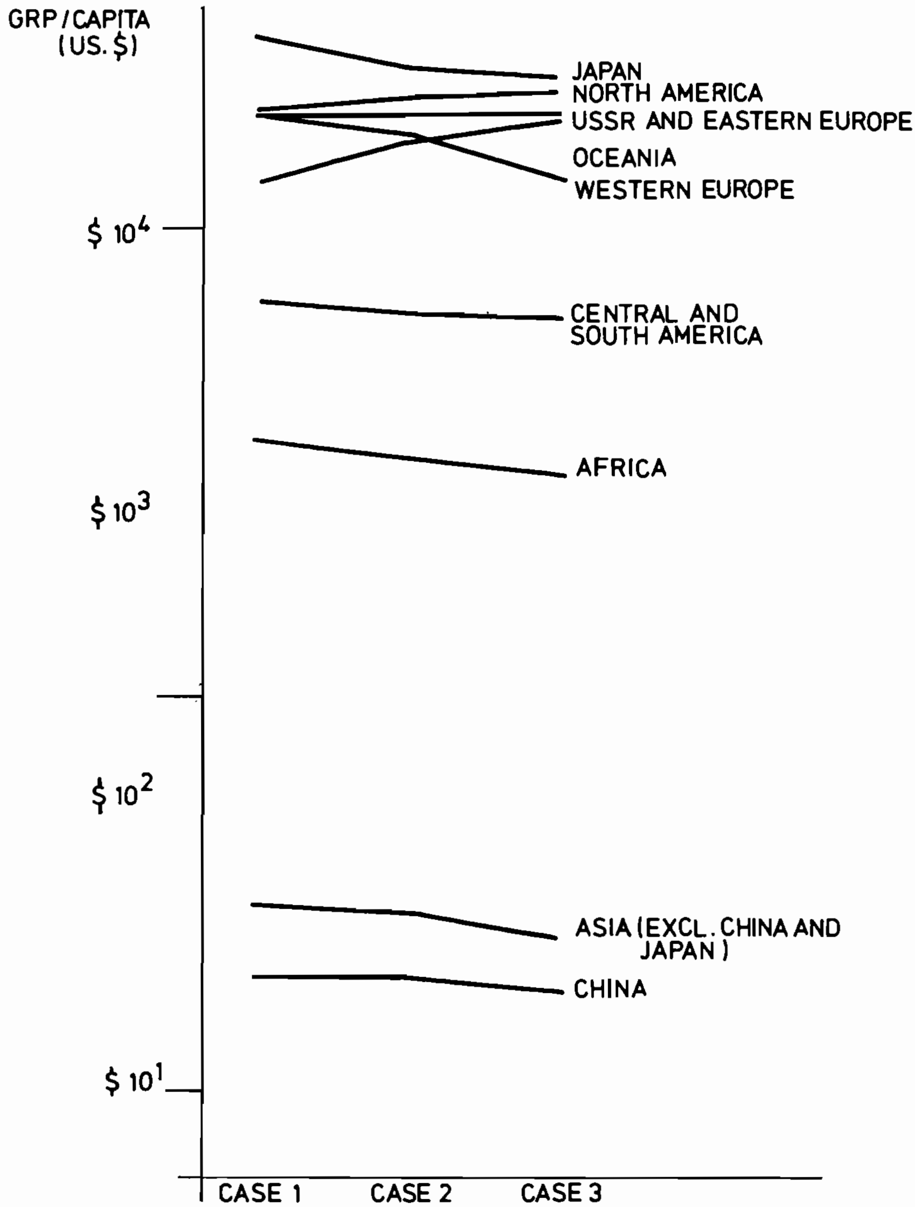

Figure 2.6. Influence of the degree of self-sufficiency on the GRP of each region. (GRP given is that for the year 2010.)

Table 2. Average index of dependence for each region in AD 2010 (for development-directed form of model).

	Value for 1970	Case 1 (no emphasis on self-sufficiency)	Case 2 (some emphasis on self-sufficiency)	Case 3 (strong emphasis on self-sufficiency)
North America	0.194	0.482	0.036	0.037
Oceania	0.082	1.114	0.628	0.180
Western Europe	0.185	0.283	0.497	0.134
Japan	0.182	0.579	0.058	0.067
Soviet Union & Eastern Europe	0.120	0.247	0.073	0.067
Central & South America	0.233	0.696	0.309	0.151
Asia (excluding China & Japan)	0.804	0.843	0.688	0.400
Africa & Middle East	0.277	0.612	0.378	0.130
China	0.400	0.806	0.800	0.552
Average for all regions	0.276	0.629	0.385	0.190

index of dependence" of each region for each of the three cases is given in Table 2.

By comparing Cases 1 and 2 in Figure 2.6 we notice that the degree of emphasis supposed in Case 2 leads to some changes within the advanced nations, but does not adversely affect the development of the poorer regions to any significant degree. When self-sufficiency is more strongly emphasized, however, as in Case 3, then the GRP of North America and Oceania with their abundant farmland and natural resources increases, while the GRP drops for the heavily populated regions such as Japan, Western Europe, and the developing nations in general.

At present, we see in the policies of the U.S.A. and Australia a kind of Monroeism. We should strongly demand that these nations recognize the way this works against development and change their policies.

Foreign Aid and the Industry Re-Distribution Plan

Our industry re-distribution plan is actually a form of indirect foreign aid whereby the advanced countries cooperate to facilitate the development of the less wealthy nations. Now let us take a look at the effect that the traditional form of economic aid would have within the framework of the world industry re-distribution plan.

To obtain some concrete results we used our model to compute the effects that would appear after 40 years under a policy of economic aid to the developing nations. For comparison we again made the "production-oriented" and the "development-oriented" runs, but this time incorporating a policy of aid from the advanced to the developing nations. Many forms of aid are possible, but we assumed one of its ideal forms: 1 percent of the total GNP of the advanced nations is given annually as untied non-project aid in the form of investment capital. The overall gross world product for the various cases is shown in Table 3.

Table 3. The effect of foreign aid on the gross world product--results for AD 2010; unit is 10^{12} U.S. $.

	Without Foreign aid	With Foreign aid	Difference
Production-oriented form	44.66	45.49	+0.83
Development-oriented form	42.48	44.91	+2.43

Areas for Further Investigation

The industry re-distribution plan has, in the limited investigation we have made so far, shown itself to be a very effective way to help the developing nations within the framework of realistic world restraints. But our investigations of this plan are far from being completed, and so we would like here, at the conclusion, to list the points which still require investigation.

1) Findings to be expected from sensitivity analysis of the model. As mentioned in the beginning of this section, the parameters we have used in the model might change their values with time, and so each of these values must be checked carefully--not only their numerical values, but also the sensitivity of the result to variations in these values. The results presented here have all been checked to ensure that they are not unreasonable or unrealistic; we do feel, however, that further useful findings will come from pursuing this analysis more thoroughly. There are some effects in our model which are very sensitive to parameter changes, and so no conclusions can be based on them.

In both the production-oriented and the development-oriented runs, the policy of economic aid slows down the growth rate of the advanced regions while accelerating that of the developing regions. In both cases, though, the policy of economic aid produces a large gross world product 40 years hence than does the no-aid policy. The increase of gross world product caused by aid in the development-oriented run is three times larger than that caused by aid in the production-oriented run.[4] This difference indicates that the economic aid is more effective within the framework of the development-oriented world economy. The reason is that the economic aid received is invested in industries that contribute more to development because of their higher capital efficiency. Also, the re-distribution of industry ensures that the developing nations have adequate markets for their developing production.

We found, for example, that the pattern of industry distribution in the advanced nations--except for the increase of the agriculture sector in North America and Oceania--changed considerably when the service-industry portion of the GRP was changed only slightly. For this reason, we realize that, at the present stage of our work, it is not possible to gain any detailed knowledge about the desirable industry pattern in the advanced nations. We intend to pursue this line of investigation much more thoroughly.

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[4]Later improvements in the data used in our model may change these figures, and so they should not be given absolute significance.

2) Improving the data. There are many imperfections in the data used, and there are many points about which data must be collected and evaluated. For example, we would like to obtain improved data about the productivity of various soils, about the regional differences in the consumption pattern expressed as a function of income, and about the regional input-output matrix and its variation with time and as a function of income.

3) Influence of factors omitted from the industry model. Our industry model is a simple one which omits a number of factors. Among the more important of these are the labor supply and the changes in price. In the future, we must see how these factors, when introduced, will affect the results.

4) The effect of freight transportation. By allowing an economic policy of self-sufficiency to play some role in the behavior of the model, we implicitly acknowledged that transportation from one region to another should be held down. However, the factor of transportation of manufactured goods from one region to another does not appear explicitly in the model, and as such is not considered. In reality, shipping manufactured goods back and forth from one region to another would use up energy resources and also cause prices to increase. This would work against the type of re-distribution of industry we propose, and so we intend to investigate this point more thoroughly.

5) Effect of regional conditions. The industry re-distribution plan we presented has taken up the problem in a global way, as well as dealt with the physical and material aspects of each region. To further refine this plan to fit the real world, we must also look deeply into the political, economic, and cultural conditions of each region. To this end we will very likely have to adopt qualitative and static analytic methods to be used in conjunction with our dynamic optimization method. We believe that only through a synthetic combination of these two methods of analysis can we indicate how each region should develop in the future.

Appendix: Details of the Models (Chapter 2)

A. EXPLANATION OF THE SYMBOLS

$i = 1,2,\ldots,N$: subscripts of the regions;

$j = 1,2,\ldots,M$: subscripts of the industries;

V_{ij}: value added produced, in the i-th region, by the j-th industry;

D_{ij}: consumption demand, of the i-th region, for the commodities produced by the j-th industry (in the following, abbreviated as "j-th commodity");

I_{ij}: investment demand, in the i-th region, by the j-th industry;

H_{ij}: investment demand, in the i-th region, for the j-th commodity;

$\underline{K}$: transformation matrix for the investment demand (same for all $i \neq 1,2,\ldots,N$);

Let $\underline{I_i}$ be defined as $(I_{i1}, I_{i2}, \ldots, I_{iN})$, and $\underline{H_i}$ as $(H_{i1}, H_{i2}, \ldots, H_{iN})$. Then, between these terms the following relation exists:

$$H_i = K \cdot I_i, \text{ for all } i = 1,2,\ldots,N;$$

U_{ij}: gross product, in the i-th region, of the j-th industry <u>less</u> intermediate inputs;

G_{ij}: gross regional product (GRP) of the i-th region, i.e.,

$$G_i = \sum_j V_{ij} = \sum_j U_{ij};$$

x_i : *per capita* GRP of the i-th region;

P_i : population of the i-th region; x_i and P_i are related as follows:

$$G_i = P_i x_i;$$

K_i : *per capita* investment demand, in the i-th region, for all the commodities;

D_{ij} : per capita consumption demand, in the i-th region, for the j-th commodity.

A_i : input coefficient matrix for the i-th region;

Kv_{ij}: rate of the value added, in the i-th region, of the j-th commodity;

<u>Definition:</u>

$$\underline{Kv}_1 = \begin{bmatrix} kv_{i1} & & \\ & \ddots & \\ & & Kv_{iM} \end{bmatrix} ;$$

g_{ij}: demand-supply gap, in the i-th region, for the j-th commodity, i.e.,

$$g_i = \underline{U}_i - \underline{D}_i - \underline{H}_i \quad ;$$

$$g_i \cdot = \sum_j g_{ij} \quad ; \text{ and}$$

$$g \cdot i = \sum_i g_{ij} \quad ;$$

K_{ij}: capital stock, in the i-th region, of the j-th industry;

c_{ij}: marginal capital coefficient, in the i-th region, for the j-th industy;

BR_i: crude birth-rate for the i-th region;

DR_i: crude death-rate for the i-th region;

DT : computation interval;

S_i : area of arable land in the i-th region;

Sp_i: area of potentially arable land in the i-th region;

S_{Ti}: total area of the i-th region;

E_{ij}: amount of energy consumption, in the i-th region, by the j-th industry;

B. PARTITION OF THE REGIONS AND THE INDUSTRIES

The world has been partitioned into the following nine regions:

1. North America,
2. Oceania,
3. Western Europe,
4. Japan,
5. Soviet Union and Eastern Europe,
6. Central and South America,
7. Asia (exclusive of Japan, Middle East and China),
8. Africa and Middle East,
9. China.

The industries have been classified as follows:

1. Agriculture (inclusive of forestry and fishery),
2. Light industry (inclusive of construction),
3. Heavy industry (inclusive of electricity),
4. "Knowledge-intensive" industry (for the present, mainly modern assembly industry),
5. Service industries,
6. Mining (crude petroleum only; the rest of the mining is included under 5).

C. THE MODELS OF DEMAND AND SUPPLY

Under "demand" we understand here not actual demand but what might be called potentially desirable demand, which have been deemed determinable as a function of per capita GRP. As already mentioned in the text, considering the mechanism of the correction of the demand-supply gap, it is always assumed that demand exceeds supply and that the value of the fraction of demand over production decreases monotonously as is shown in Figure C.1. The demand is composed of investment as well as of consumption demand. Figure C.1 also shows the propensity to invest as a function of per capita GRP of the region. In order to obtain consumption demand, the consumption pattern of each item (see the list under F.10 below) as a function of per capita GRP

(Figure C.2) has been multiplied by a transformation matrix, thus obtaining consumption demand for the commodities produced by the eight industries (Figure C.3) The pattern has been constructed, referring to the data of Japan. It should be ameliorated with the data of other countries which will be adopted hereafter. Figure C.4 shows the consumption elasticity of total demand for each commodity i (i=1,2,.....,N), i.e., the fraction of that percent increment of total demand, commodity by commodity, which has been induced by the increases in consumption of various commodities, over the percent increment of the total (or summed-up) consumption.

The supply model adopted here is as simple as equation (2.1) indicates. The data available now are not sufficient to determine a reliable supply model, but at the moment the marginal capital coefficients may be imputed in the following way, for the respective industries.

Agriculture. In order to allow for the finiteness of available land, as well as for that of its fertility, the following assumptions have been made. Agricultural investment is divided into two parts: one is for investment on the already cultivated land, and the other is for reclamation and clearing of virgin soil. It is assumed that at each time-point capital is laid down for whichever purpose is more efficient than the other. This assumption would not seem to be too unrealistic if the computation interval DT is taken short enough (say, a year), so that the alteration of both types of investment would not be too uneven.

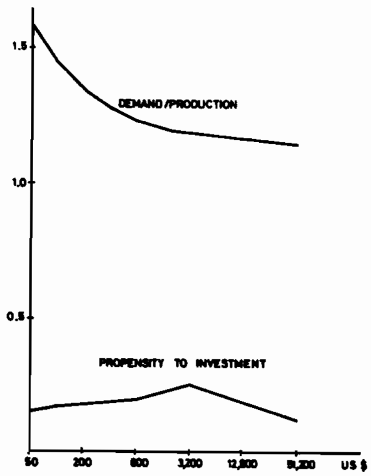

Figure C.1.

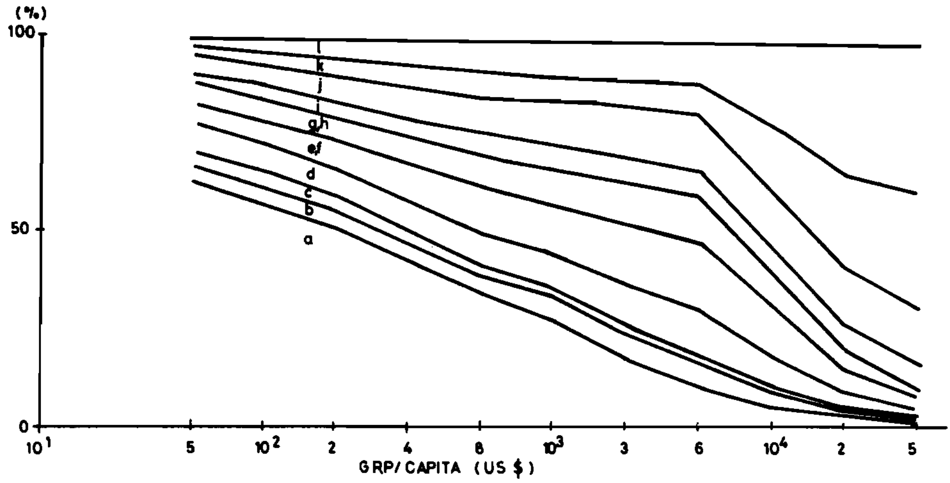

Figure C.2. Consumption pattern.

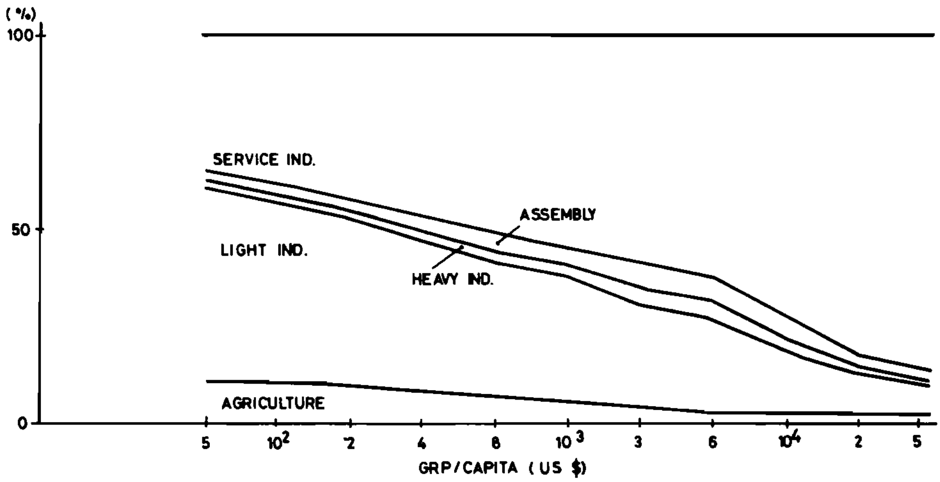

Figure C.3. Consumption demand for the commodities.

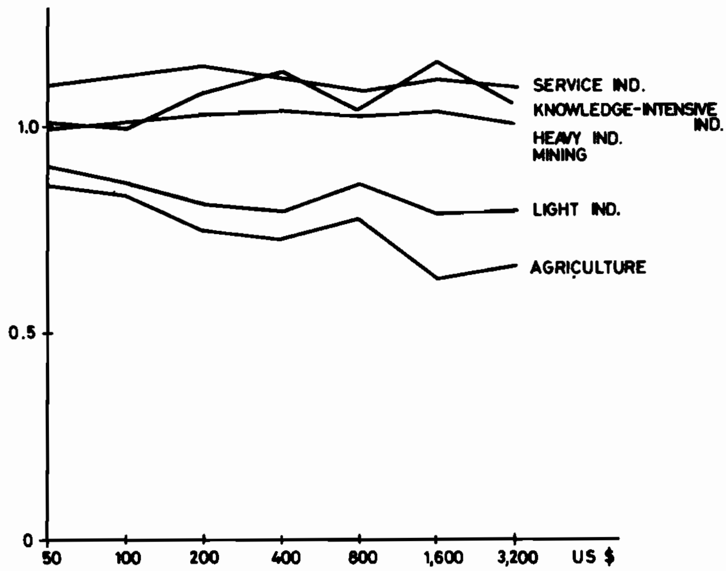

Figure C.4. Consumption elasticity of total demand for each commodity.

The crop per unit area, $\underline{y}$ depends on the capital stock per unit area (Figure C.5), as well as on the rate of cultivation, S_i/Sp_i (Figure C.6); the cost of reclamation and clearing, r, depends on the rate of cultivation only, that is, $r(S_i/Sp_i)$. (Figure C.7).

Under these assumptions, the marginal capital coefficients are calculated as follows, according to the types of investment.

a) Case of capital investment on existing land. Since the equation

$$y = y_1(K/S) \cdot y_2(S/Sp) \tag{C.1}$$

holds, where K stands for Ki_1 (capital stock of agriculture), the following obtains:

$$\Delta V = \left[y_1\left(\frac{K + I \cdot DT}{S}\right) - y_1\left(\frac{K}{S}\right) I \right] \cdot y_2\left(\frac{S}{Sp}\right) \cdot S'$$

$$\doteq DT \cdot y_i\left(\frac{K}{S}\right) I \cdot y_2\left(\frac{S}{Sp}\right) \quad . \tag{C.2}$$

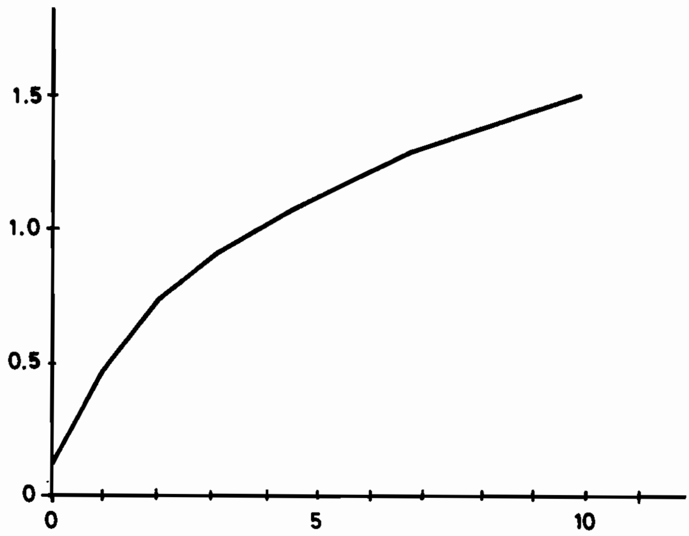

Figure C.5. Crop per unit area.

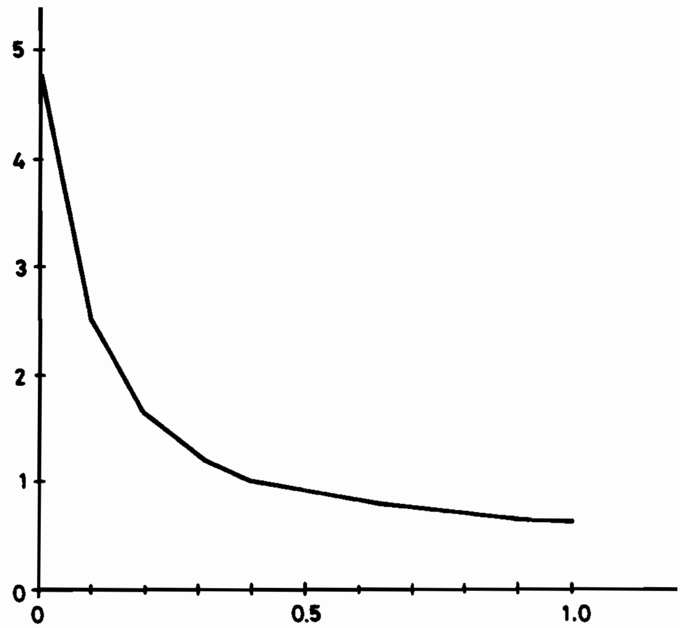

Figure C.6. Cost of reclamation and clearing.

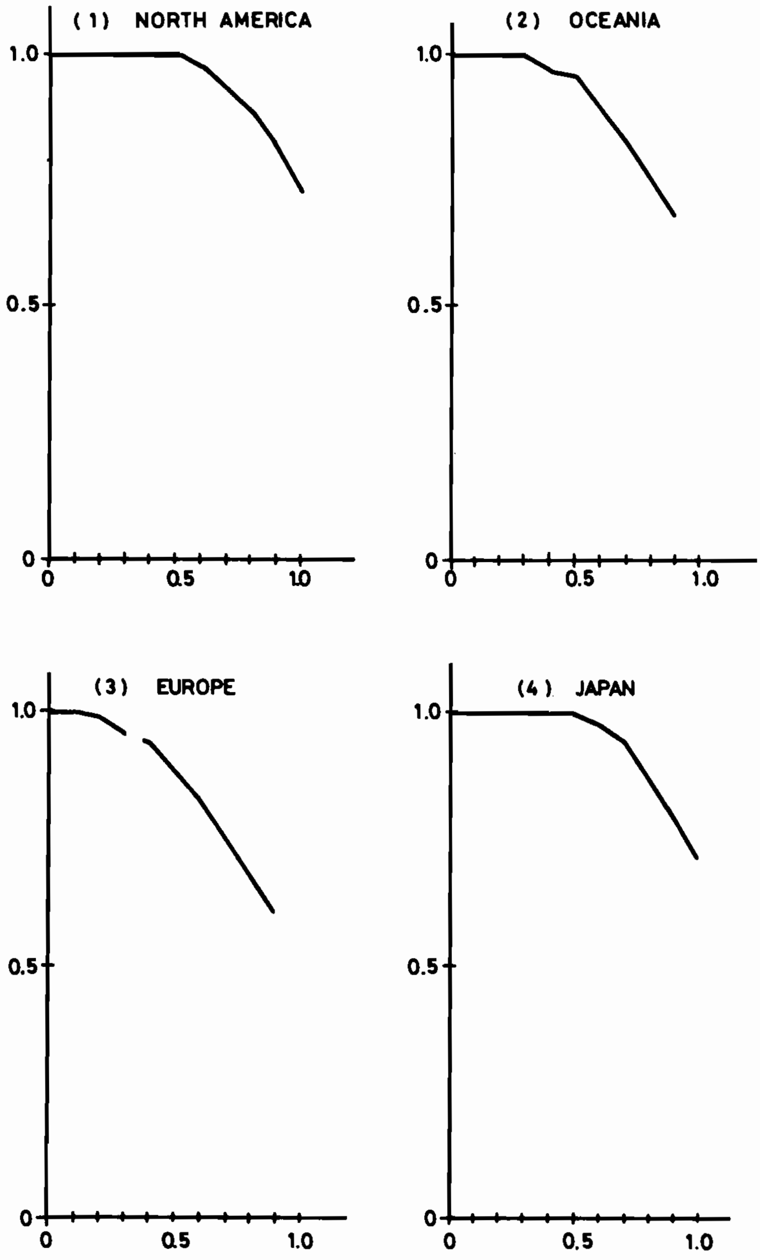

Figure C.7. Relative efficiency of land.

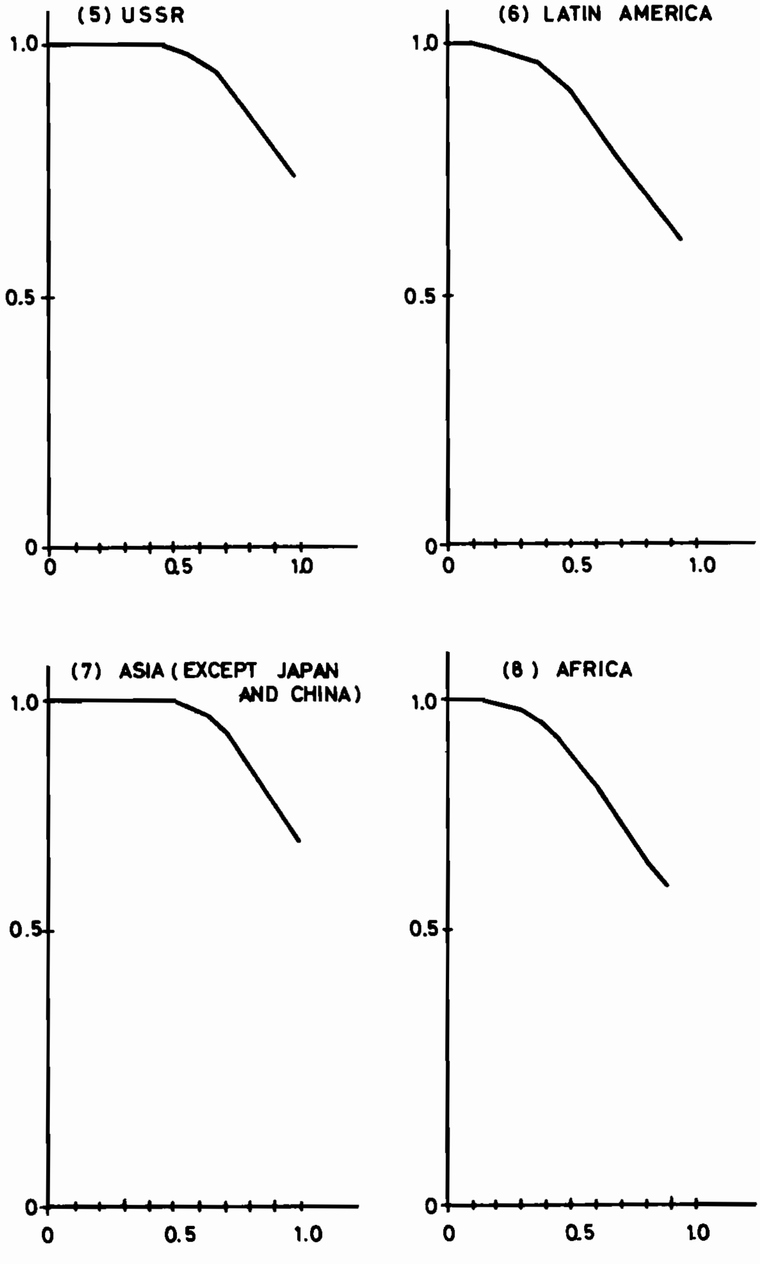

Figure C.7. Relative efficiency of land (continued).

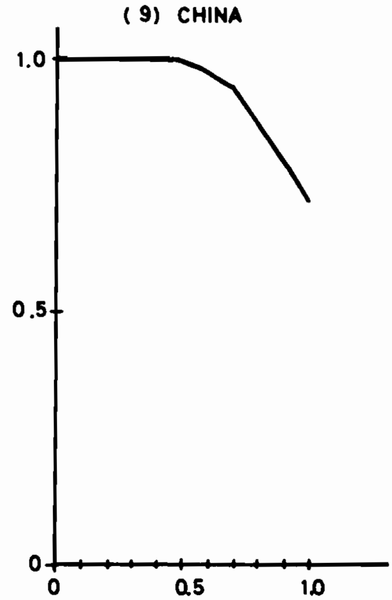

Figure C.7. Relative efficiency of land (concluded).

Hence, the marginal capital coefficient equals,

$$\frac{1}{Y_i\left(\frac{K}{S}\right) \cdot Y_2\left(\frac{S}{Sp}\right)} \qquad \text{(C.3)}$$

b) Case of reclamation and clearing. Let $I = I_1 + I_2$, equal the total investment, where I_2 is reclamation investment, and let I_1 be used for the capital investment on the newly reclaimed land. Thus,

$$\Delta S = \frac{I_2 \cdot DT}{r\left(\frac{S}{Sp}\right)} \; ; \qquad \text{(C.4)}$$

$$I_1 = \Delta S \cdot \frac{K}{S} \; . \qquad \text{(C.5)}$$

Hence, the area of the newly opened land, S, can be written as

$$\Delta S = \frac{I \cdot DT}{r + \cdot \frac{K}{S}} \tag{C.6}$$

Since

$$\Delta V = y\Delta S = \frac{yI \cdot DT}{r + \frac{K}{S}} \ , \tag{C.7}$$

the marginal capital coefficient equals

$$\frac{r\left(\frac{S}{Sp}\right) + \frac{K}{S}}{y_1\left(\frac{K}{S}\right) \cdot y_2\left(\frac{S}{Sp}\right)} \ . \tag{C.8}$$

As assumed above, the smaller of the (C.3) and (C.8) is taken as the actual marginal capital coefficient.

Manufacturing industries. Statistics available do not yield a separate coefficient for each of the three industries. In statistical terms (see F.14 below), the trend of the capital coefficients for all three industries taken together shifts upwards as per capita GRP increases. On the other hand, it would be natural to assume that, as a rule, as the level of income per capita increases, the level of knowledge also upgrades, as does the productive efficiency of the region. In this case, the coefficients should tend to diminish as per capita GRP increases. These two observations may seem to be contradictory. However, it might be solved by considering the differences in the industrial structure within the manufacturing industry between developed and developing regions. Taking this into consideration, the curves indicating the marginal capital coefficients have been shaped as shown in Figure 2.2 in the text.

Service industries. According to the actual data, no significant difference has been found among per capita GRP levels, as has been shown in Figure C.8.

Mining. Only petroleum is considered. Current marginal capital coefficients have been imputed from the references shown below, but no inferences are available as to the shifts in their values as the resource approaches the depletion level. Hence, we have assumed these as shown in Figure C.9.

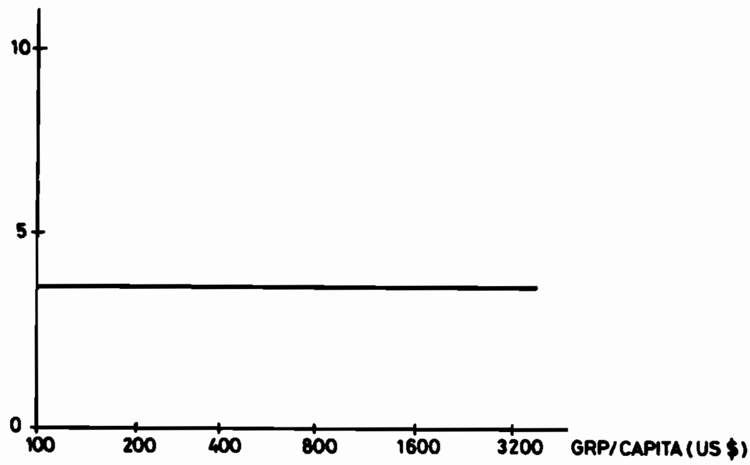

Figure C.8. Marginal capital coefficient in service.

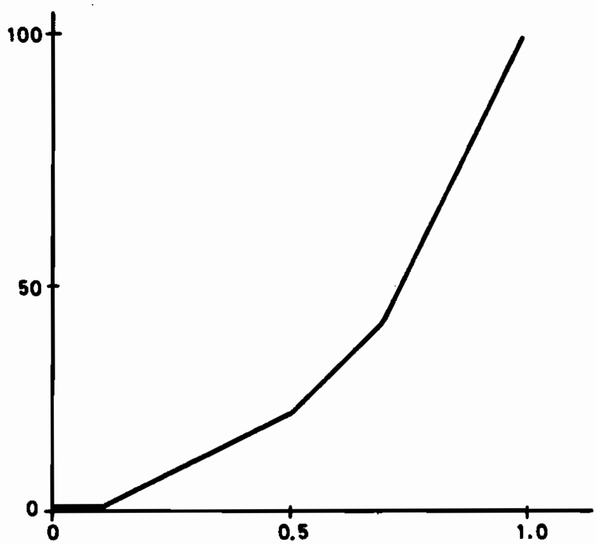

Figure C.9. Marginal capital coefficient in mining.

D. OPTIMIZATION OF ONE-STEP TYPE CRITERION FUNCTION.

A criterion function considered here is the following:

$$J_1 = \sum_i WR_i g_i'^2 + \sum_j WC_j g_j'^2$$

$$+ \sum_i WA_i g_{i1}'^2 + \sum_i WL_i g_{i2}'^2 + \sum_i WH_i g_{i3}'^2$$

$$+ \sum WI_i g_{i4}'^2 + \sum_i WE_i E_i'^2 \quad , \tag{D.1}$$

where E_i is the amount of energy consumption (excluding that of household expenditure) in i-th region; this is represented by,

$$E_i \triangleq \sum_j \text{(energy consumption coefficient in j-th}$$

$$\text{industry)} * V_{ij} \quad . \tag{D.2}$$

The meaning of each of the terms of equation (D.1) is as follows.

$WR_i g_i'^2$: degree of supply-demand gap in i-th region;

$WC_j g_{ij}'^2$: degree of supply-demand gap in j-th commodity;

$WA_i g_{i1}'^2$: degree of supply-demand gap of agricultural commodity in i-th region;

$WL_i g_{i2}'^2$: degree of supply-demand gap of light industrial commodity in i-th region;

$WH_i g_{i3}'^2$: degree of supply-demand gap of heavy-industrial commodity in i-th region;

$WI_i g_{i4}'^2$: degree of supply-demand gap of knowledge-intensive industrial commodity in i-th region;

$WE_i E_i'^2$: degree of energy consumption per area.

The third to sixth term of equation (D.1) represent a self-sufficiency of each commodity in case the corresponding coefficient is positive.

A prime "," denotes that the corresponding value is a predicted one of the next step. Therefore we determine an investment I_{ij} so as to minimize J_i, the predicted value of the criterion function of the next step.

Coefficients in equation (D.1) are as follows:

$$WR_i = WR_i \cdot \frac{P_i}{G_i^2 \cdot \sum_i P_i} , \tag{D.3}$$

$$WC_j = \frac{WC_{j0}}{\sum_i V_{ij} \cdot \sum_{ij} V_{ij}} , \tag{D.4}$$

$$WA_i = \frac{WA_{j0}}{V_{i1} \cdot \sum_i V_{i1}} , \tag{D.5}$$

$$WL_i = \frac{WL_{i0}}{V_{i2} \cdot \sum_i V_{i2}} , \tag{D.6}$$

$$WH_i = \frac{WH_{i0}}{V_{i3} \cdot \sum_i V_{i3}} , \tag{D.7}$$

$$WI_i = \frac{WI_{i0}}{V_{i4} \cdot \sum_i V_{i4}} , \tag{D.8}$$

$$WE_i = \frac{WE_{i0}}{ST_i \cdot \sum_i G_i} . \tag{D.9}$$

In equation (D.3), g_i/G_i is the ratio of deficiency of commodities. Population P_i modifies this term. WR_{i0} shows a relative weight between each term.

Equations (D.4) to (D.9) have about the same meaning as equation (D.3).

G'_{ij} (estimate of next step g_{ij}) and various coefficients (equations (D.4) to (D.9)) are the functions of I_{ij}. This makes J_1 a fairly complex function of I_{ij}. This makes J_1 a fairly complex function of I_{ij}. To reduce computational difficulties, a few approximations are adopted.

First we regard various coefficients unchanged in each step. Second a linear approximation of G'_{ij} with respect to I_{ij} is used:

$$G'_{ij} \doteq G_{ij} + \sum_{\ell} (I - A_i)_{j\ell} \frac{1}{C_{i\ell} Kv_{i\ell}} I_{i\ell} \quad . \tag{D.10}$$

By means of these approximations J_1 becomes a quadratic form of I_{ij}.

Total investment in i-th region I_i. is subject to equality constraint (a function of GRP per capita), and each control variable I_{ij} must be non-negative. Thus the above problem with approximations is a typical quadratic programming problem. The authors solved this by the use of Wolfe's method.

The total number of control variables of this problem is 36 (4 sectors x 9 regions), while investments in service and mining sectors are determined by simple supply-demand gap algorithm instead of by optimization procedure.

The principle of determining foreign aids is simplified as follows. A developed region awards a constant fraction of its gross production as foreign aid to developing regions at the sacrifice of its total investment. A developing region accepts this foreign aid according to appropriate weights. This foreign aid simply increases a total investment in a developing region.

All cases stated in the text can be realized simply by changing parameters. For example, if we put $WR_i \triangleq 0$ in equation (D.1), the case of a stress on productivity can be realized. Also a positive value of WA_i, WL_i, WH_i, and/or WI_i shows a self-sufficiency principle.

E. DYNAMIC OPTIMIZATION

A state variable is composed of V_{ij}, value added in i-th region, i-th sector. V_{ij} is subject to a dynamic constraint,

$$V_{ij}(k+1) = V_{ij}(k) + \frac{I_{ij}(k)}{C_{ij}(k)} \tag{E.1}$$

where index k indicates a discrete time index. $[I_{ij}]$ arranged in the same order as $\mathcal{X}$ constitutes a control vector $\mathbb{U}$. This may be expressed in the following state equation form,

$$\mathcal{X}_{k+1} = f(\mathcal{X}_k, \mathbb{U}_k, \mathfrak{c}_k, k) \tag{E.2}$$

where a parameter is an array of marginal capital coefficient C_{ij}. As C_{ij} is a function of V_{ij}, equation (E.2) shows non-linearity.

The criterion function considered is,

$$J = \left[\theta_k(\mathcal{X}_k, k)\right]_{R_o}^{R_f} + \sum_{k_o}^{K_{f-1}} \phi\,(\mathcal{X}_k, \mathbb{U}_k, k) \quad , \tag{E.3}$$

where

$$\phi\,(\mathcal{X}_k, \mathbb{U}_k, k) = \sum_i WP_i * g_i^{\,2} + \sum_j WC_j * g\cdot j^2$$
$$+ \sum_i WA_i * g_{i1}^{\,2} + \sum_i WL_i * g_{i2}^{\,2} + \sum_i WH_i * g_{i3}^{\,2}$$
$$+ \sum_i WI_i * g_{i4}^{\,2} + \sum_i WS_i * g_{i5}^{\,2} + \sum_i WE_i * E_i^{\,2} \quad . \tag{E.4}$$

Terminal criterion θ is assumed to be the same type of function as ϕ. This time, investments in a service industry are also contained in control variables.

The problem of minimization of J subject to equation (E.2) is well known as the optimal control problem, the numerical solution of which is as follows.

1) Assume an initial solution $\mathbb{U}$. A solution obtained by use of one-step type optimization is good for this purpose. Solve equation (E.2) forward in time to obtain $\mathcal{X}_k(k = k_{o+1}, \ldots, k_f)$.

2) Let λ be the adjoint vector of $\mathcal{X}$. Solve adjoint equation

$$\lambda_k = \frac{\partial \phi}{\partial \mathcal{X}} + \left(\frac{\partial f}{\partial \mathcal{X}}\right)^T \lambda_{k+1} \quad , \tag{E.5}$$

backward in time to obtain $\lambda_k (k = k_{f-1}, \ldots, k_o)$.

The final value of λ_k, that is,

$$\lambda_{kf} \triangleq \frac{\partial \theta_{kf}}{\partial \mathcal{X}_{kf}}$$

can be evaluated easily.

3) Let $H \triangleq \phi + \lambda_{k+1}^T f$ be a Hamiltonian function. Evaluate the derivative of H with respect to U .

$$\frac{\partial H}{\partial U|_k} = \frac{\partial \phi}{\partial U|_k} + \left(\frac{\partial f}{\partial U|_k}\right)^T \lambda_{k+1} \quad . \tag{E.6}$$

4) Owing to the inequality constraints ($I_{ij} \geq 0$) and to equality constraints ($\sum_j I_{ij}$), it is sometimes impossible to change the control vector $U|_k$ in the direction of $-\frac{\partial H}{\partial U|_k}$. A feasible direction of change of u_k, is therefore the projection of the gradient vector onto constraint hyperplanes. Let this projection vector be $-\left[\frac{\partial H}{\partial U|}\right]_p$.

A new control vector $U|_k{}'$ is written as

$$U_k{}' = U_k - K \left[\frac{\partial H}{\partial U|_k}\right]_p \quad , \tag{E.7}$$

where K is chosen so as to minimize a criterion $J(U_k')$. This one-direction search is the most time consuming in computation of optimal control problem, and so an efficient way of one direction search is being sought. Among various methods, the authors have adopted the golden section search method for its simplicity and numerical stability.

5) By using the new control vector U'_k, solve equation (E.2) forward in time to obtain X_k. Return to point 2) and carry out this exercise.

F. SOURCES AND METHODS OF DATA-PREPARATION

1. The area of arable land: Statistical Yearbook, New York, United Nations, 1970.

2. The area of potentially arable land: processed from the data by continent given in The World Food Problem, Vol. II, The White House, Washington, D.C., 1967.

3. Total land area: Statistical Yearbook, New York, United Nations, 1970.

4. Population: estimations according to Production Yearbook, Rome, FAO, 1971.

5. The ultimate reserves of crude petroleum: data by region from Considerations on the Oil Industry (Japanese), Tokyo, 1968, also Statistical Yearbook, 1971.

6. Unit energy consumption by industry. Calculated by the following formula:

$$\frac{\text{Energy consumption of the industry}}{\text{Value added produced by the industry.}}$$

Both terms of the formula have been obtained from the following sources:

a) Energy consumption by industry;

b) Energy Matrix (Japanese), Tokyo, 1972;

c) Production of value added.

Consolidated Interindustrial Correlation (I-0); Table of Japan for 1970. Although these data are for Japan, they have been, for convenience, applied to all the regions. They will be replaced by the data of such regions after data from these regions become available.

7. Interindustrial correlation (I-0) matrix: The Interindustrial Correlation Table of Japan for 1965, edited by The Administrative Management Agency, et al., has been used. These data for Japan have been applied to the world.

8. Agricultural capital: Annual surveys of agricultural household for 1970, published by the Ministry of Agriculture of Japan (1972) have been used, together with data for the number of tractors, taken from Production Yearbook.

9. Production of value added: basically, the value added of each industry for 1970 has been calculated by extrapolating the data for 1963, using appropriate indices. Proportions between the value added of the industries for 1970 have been obtained by aggregating by region the data from Yearbook of National Accounts Statistics, 1971, Vol. 3, New York, United Nations. Partition within the manufacturing industry has been calculated from Statistical Yearbook, New York, United Nations, 1970, which also gives the indices for 1970. However, the proportions relating to Africa have been calculated by directly aggregating the data for 1970, and the partition of the manufacturing industry has been aggregated from The Growth of World Industry, Vol. I, New York, United Nations, 1970.

   The GRP for North America, Europe, and Japan have been obtained as real numbers; GRP for the other regions have been obtained by extrapolating the figures for 1969. The GRP for the Soviet Union and Eastern Europe have been calculated from the data for "material production" of the countries within the block. But, as is well known, the data include only part of "service" production, and so the correction has been made to the data for 1969, so that the proportion of "services" in the GRP of the year is 45 percent; then it has been extrapolated, thus obtaining the value for 1970.

   The amount of the production of "crude petroleum" is found in Statistical Yearbook, New York, United Nations, 1971, and using the conversion rate of 2 dollars/barrel; figures in dollars have been calculated.

   Data for China have been estimated mainly from Long-run Perspectives of the Chinese Economy, Vol. IV (1), ed. by Shigeru Ishikawa, Tokyo, The Institute for Asian Studies, Chapters 2 and 3.

10. Consumption demand: this can be obtained by multiplying the consumption patterns by a transformation matrix. The consumption patterns are found in Yearbook of National Accounts Statistics, New York, United Nations, 1971, for the following items which have been translated into functions on per capita GRP. These are:

1) Food;

2) Beverages;

3) Tobacco;

4) Clothing and footwear;

5) Gross rent, fuel and power;

6) Furniture, furnishings and household equipment and operations;

7) Medical care and expenses;

8) Transport and communication;

9) Recreation, entertainment, education and cultural services; and

10) Miscellaneous goods and services.

The transformation matrix has been calculated using the sources mentioned in 7. and 8. above, as well as several household surveys. These data for Japan have been applied to the rest of the world; a collection of the world data is needed.

11. Investment demand: data from Statistical Yearbook, New York, United Nations, 1971, have been transformed into functions on per capita GRP.

12. The efficiency of agricultural production: Figure C.5 has been prepared from Production Yearbook, Rome, FAO, 1971.

13. Reclamation and clearing cost: taking into consideration the descriptions of The World Food Problem, Vol. II, assumptions have been made as shown in Figure C.7.

14. Marginal capital coefficients: since figures about value added and, especially, gross investment are not available in terms of constant prices for some countries, the following expedient has been used. That is, capital coefficients have been calculated for each year in terms of current prices, and then the mean value has been taken of these coefficients over the period concerned. The yearly increments of both value added and of gross investment for the industries over the period of 1961-70 have been calculated from Statistical Yearbook, New York, United Nations, 1970.

These mean values have been plotted on the graph with the logarithmic abscissa indicating per capita GRP. This diagram has been used in the assessment of the applied capital coefficients (see C. above).

15. Crude birth and death rates: data from Demographic Yearbook, New York, United Nations, 1969, have been processed into functions on per capita GRP.

16. Productive efficiency of land by region: the descriptions in The World Food Problem, Vol. II, l.c., ch. 7, on the appropriateness of various soil groups, and, especially, data (l.c.) on the proportions of already cultivated area in the potentially arable area of each soil group have been allowed for, and these soil groups have been ranked into four grades. Assuming, rather arbitrarily but not completely groundlessly, that in each region land of higher grade is used before that of lower grade, we attributed relative productive efficiency, ranging from 1 to 0, to each additional area drawn into cultivation. Thereafter, depending on some rather arbitrary rule, the average efficiency of each additional unit area was calculated. It goes without saying that more detailed research is needed.

On a Multi-Nation-Link Economic Model[1]

Akira Onishi

RESEARCH OBJECTIVES

The present age corresponds to a historical stage in which relations of mutual dependence among nations are increasing, and the need for reciprocal understanding and cooperation is heightened. This is especially true in the economic field, because the economic policies adopted by advanced industrial countries exercise a great impact on the developing nations. The economic policies adopted by the developing countries give rise to alterations in the flow of trade and investment by the advanced industrial countries, with consequent repercussions to the entire process of economic development. Of course, the relative "degrees of sensitivity" to these two-way impacts will differ. Generally speaking, most relationships involve a more sensitive reaction by the developing countries to an impact caused by the advanced countries than would be true in the reverse case. However, this general relationship does not always hold true. In the case of raw materials policies--a prime example being the "oil strategy" of the Arab countries--severe dislocations may be suddenly inflicted on advanced industrial countries such as Japan. And these shocks received by advanced industrial countries tend, in due course, to have repercussions on the developing countries.

Within the framework of such mutually dependent international relationships, there is the urgent need to look at the interacting development patterns of both the "northern" advanced industrial economies and the "southern" developing nations' economies with a view to making analyses through the use of models. By doing so, we can advance the search for economic policies which can contribute to the process of finding solutions for the North-South problem.

Japan has a responsibility to cooperate in seeking solutions to the North-South problem, especially in Asia. Looking to the 1980s, it may be expected that Japan's economic impact will have an expanding influence on Asian developing countries, even greater than that anticipated. No Japanese economic policy may be formulated without regard to these realities. The same realities apply also to Asian developing countries.

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[1]This study was carried out as a part of 1973/74 research projects at the International Development Center, Tokyo.

Since mutually dependent relations in the economic sphere are gaining strength, it is becoming increasingly difficult for Asia's developing countries to formulate economic development plans without regard to the impact of the Japanese economy. The main objective in developing the multi-nation-link economy model lies in doing research into possible desirable patterns of economic relations between the advanced and the developing countries.

One purpose of this study is to seek ways of reassessing the North-South relations so as to harmonize national development plans and policies of advanced and developing countries. Attempts at projecting economic growth and foreign trade of developing countries have been made by United Nations and others. However the interdependency of economic growth of each country within a region was not clarified. The majority of developing countries in Asia have established medium or long-term development plans. However, these plans pay little attention to the facts that the economic development of these countries is dependent on intraregional trade, and that possibilities for realizing these plans are interrelated not only with various domestic factors but also with the economic development of other countries. Therefore, this study considers the relationship of economic growth and trade of a group of countries in the light of harmonizing national development plans and policies of the advanced and the developing countries. Thus a multi-nation economic model is needed. However, in the past, economic projections of these countries have been made within the limit of the economy of an individual country, and no example exists of the application of dynamic multi-nation modeling for a group of advanced and developing countries. This paper presents a trial application of a multi-nation-link economic model to a number of countries.

AREAS OF RESEARCH

The countries involved in the present research project are the 16 member nations of the Development Aid Committee of the OECD, and 15 developing nations of Asia. The former group consists of the following: Australia, Austria, Belgium, Canada, Denmark, Federal Republic of Germany, France, Italy, Japan, the Netherlands, Norway, Portugal, Sweden, Switzerland, the United Kingdom and the United States. The latter group consists of the following: Burma, Hong Kong, India, Indonesia, Iran, Republic of Korea, Malaysia, Pakistan and Bangladesh, which on this study are taken together, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and South Vietnam. Because of limitations in the statistical data available, Nepal, Western Samoa, the People's Republic of China, North Korea, North Vietnam, the Mongolian People's Republic, and other countries of Aisa were excluded from the present study, although in the future it will no doubt be-- come necessary to include them within the model's framework. The development of the multi-nation-link economic model and the accompanying forecast operations are as far as we have been able to determine the first worldwide attempts to do such work. The base year chosen in the forecasting operations was 1970, and the target year was taken as 1980. The forecasts yielded by the multi-nation-link economic model are designed to be of a long-range nature, taking as their focal point North-South economic relations subsequent to the 1973-74 "oil shock." Of course, we were not content with making simple forecasts based on considerations of past and present system structure; rather we designed the model with a view to attempting to make forecasts of the expected alterations in development patterns which would likely arise under the influence of a variety of different hypothetical policy formulations (policy mixes). This was necessitated by the importance of doing careful research into the exact sort of impacts caused on the developing countreis of Asia by the aid, trade and foreign investment policies of the advanced industrial nations, in particular, by Japan. Also it was judged that this type of forecasting would be useful in examining the "degree of mutual compatibility" in the various economic policies of each nation, including export and other economic-related target figures entailed in development planning.

BASIC IDEA OF MULTI-NATION-LINK ECONOMIC MODEL

There is an abundance of literature dealing with economic models, but very few of the models are applicable to developing countries. Some computable macro-economic growth models may be found in [4]. However, these models are limited to economic plans of an individual country, and do not attempt to analyze the interdependency of economic growth of a group of countries within a region. The theories of international trade have approached this problem by way of the generalization of the multi-country theory by the two commodities models or a foreign trade matrix. We believe that the simplest approach to this problem is to use the dynamic input-output model, and to analyze the interdependency of economic activity of each country. Tinbergen suggested a model of r region and h sector. [3] But input-output tables are still not available in complete form for most of developing countries; furthermore there are difficulties in finding data on investments by sector and/or making a matrix of capital coefficients for the purpose of designing a dynamic multi-sector model. In view of the time and considerable volume of work needed to compile data, immediate realization cannot be expected. Within the limits of available data, it is sensible to draft a macro-economic growth model for n countries.

Brief explanation on the basic idea of a multi-nation-link model is as follows;

Simple model

$$x_t = e_t + f_t - m_t + c_t + g_t + \Delta st \quad (1.1)$$

$$e_t = Ax_t \quad (1.2)$$

$$f_t = f_o(1 + \bar{r})^t \quad (1.3)$$

$$m_t = b^o + Bx_t \quad (1.4)$$

$$c_t = c^o + Cx_t \quad (1.5)$$

$$g_t = g^o + Gx_t \quad (1.6)$$

$$\Delta s_t = K\Delta x_t \quad (1.7)$$

Symbols

x : a column vector of n elements which denotes gross domestic product of n countries within the region.

e : a column vector of n elements which denotes intra-regional exports from country i to country j within the region.

f : a column vector of n elements which denotes a country's exports to outside the region.

m : a column vector of n elements which denotes a country's total imports.

c : a column vector of n elements which denotes a country's private consumption expenditure.

g : a column vector of n elements which denotes a country's government consumption expenditure.

Δs : a column vector of n elements which denotes a country's gross domestic capital formation.

$\bar{r}$: a column vector of n elements which denotes a country's rate of increase in exports to outside the region.

A : an a_{ij} coefficient matrix of an n x n order which denotes the coefficient of exports from country j within the region i, j = 1, 2...n.

f_o : a column vector of n elements which denotes the dimension parameters of the outer regional export function.

B : a diagonal matrix of an n x n order which indicates the total import coefficient of a country within the region.
$i, j = 1, 2 \ldots n$;
$b_{ij} = 0 \; i \neq j$.

b^o : a column vector of n elements which indicates constants of the import function.

C : a diagonal matrix of an n x n order which indicates the private marginal propensity to consume of a country within the region.
$i, j = 1, 2 \ldots n$;
$c_{ij} = i \neq j$.

c^o : a column vector of n elements which indicates constants of private consumption function.

G : a diagonal matrix of an n x n order which indicates the government marginal consumption expenditure propensity of a country within the region.
$i, j = 1, 2 \ldots n$;
$g_{ij} = 0 \; i \neq j$.

g^o : a column vector of n elements which indicates constants of the government consumption expenditure function.

K : a diagonal matrix of an n x n order which indicates the marginal gross capital coefficient.
$i, j = 1, 2 \ldots n$;
$k_{ij} = 0 \; i \neq j$.

Δx_t : $x_{t+1} - x_t$.

Δs_t : $s_{t+1} - s_t$.

t : time .

- : denotes exogenous variables.

Let us start with the simple model; (1.1) is a formula indicating the balance of national economy of each country in the region. Equations (1.2), (1.3), (1.4), (1.5), (1.6) and (1.7) denote the functional relationships between variables. In (1.2) let us suppose that the intraregional exports from country i to country j within the region are a linear function of the gross domestic product of the importing country j. The total imports of each country within the region are a linear function of the gross domestic product of the country concerned in (1.4). As regards private and government consumption function (1.5) and (1.6), the same linear relationships between consumption expenditure and gross domestic product of the country are assumed, respectively. Furthermore, as to the investment function, a similar linear relationship is supposed between capital stocks and gross domestic product of each country in (1.7). There will exist some cases where non-linear function is considered more adequate than a linear one, but here a linear relationship is supposed. The defects of linear function should be corrected to some extent by the modification of estimated parameters.

The f function (1.3) which indicates the exports to outside the region is not necessarily linear, but the time paths of its development are supposed to be predetermined exogenously. If the time paths of exports of the countries to outside the region are determined exogenously, it may be possible to obtain the following endogenous variables in this model the growth paths of the gross domestic product x, private and government consumption expenditures (c and g), gross domestic capital formation Δs, intraregional trade e, total imports m.

When (1.1) is transferred into the matrix form, taking into consideration the functional relationships from (1.2) to (1.7), we arrive at:

$$x_t = Ax_t - b^o - Bx_t + c^o + Cx_t + g^o + Gx_t + K\,x_t + f_t \quad , \qquad (1.8)$$

where (1.8) is transformed to the reduced form; this is as follows:

$$x_t+1 = (I + K^{-1}Q)x_t - K^{-1}R_t \qquad (1.9)$$

where

$$[I - (A - B + C + G)] \equiv Q, \text{ and}$$

$$(-bo + c^o + g^o + f_t) \equiv R_t \quad .$$

The multi-nation-link economic model is an example of model analysis of the interdependency of economic growth of a group of countries. The analysis of the more complicated aspects of economic development of many nations by this simple macro-model is not possible. In this model, the economy is unified into a single macroscopic sector, but it is possible to approach the problems of economic growth of a group of countries, (which include the mutual relation of industrial sectors) by creating multiple sectors. This model supposes a linear relationship in various economic variables; however, when replaced by a non-linear relationship, this becomes more realistic. Further it will be possible to suppose more complicated functional relationships by increasing the explanatory variables of the model. The model's analyzing techniques are closely related to various problems such as the treatment of statistical data, the econometric method of estimating parameters, the computing capacity and costs of electronic computers, but it may be necessary for projection models to become more complicated, more diversified and larger. This simple model is only at the initial stage; and will be developed into a large-scale model which will be explained in the following sections.

THE MULTI-NATION-LINK ECONOMIC MODEL

The study examines the relationships of mutual economic dependence among the 16 advanced and 15 developing countries, by means of multi-nation-link economic model using orthodox econometric methods. There are two types of the multi-nation-link model developed by the author: type 1 is the "production-oriented model"; and type 2 is the "demand-oriented model."

The development of the multi-nation-link model occured at the same time as the oil crisis, and because of the newly produced change in the international environment, we became aware of the urgent need to forecast global economic movements in the post-oil crisis era. The crisis gave birth to new inflationary pressures affecting international society, and in the design of our model special efforts were made to provide the apparatus for explaining these inflationary pressures. Also, the new conditions of "transmission of inflation between countries" may be explained using the model.

A condensed introduction to the most important features of the two types of newly developed "multi-nation-link" models is given below:

First, the multi-nation-link model has the merit of being able to forecast, with a view to mutual compatibility, the course of economic growth of individual countries that may have inter-dependent relations. The model as permits a similar forecasting for the world economy as a whole, providing a sort of index of the degree of compatibility between the economic policies of the advanced and developing nations. And it is precisely here that one may find the most impelling reason which led the author to initiate the development of the multi-nation-link model.

Secondly, with a view to simplifying the model, the number of both structural and definitional equations has been reduced as far as possible. The model's size is of giant proportions; there are roughly 2,000 equations. To make the many calculations involved, a large-scale electronic computer must be used.

Thirdly, many different types of variables are to be found in the model's structural equations, and rather than impose the compulsory use of the very same explanatory variables for all countries, we adopted the procedure of selecting the "optimum combination of variables" for each country. In other words, depending on the country concerned, the computer is programmed to automatically exclude relatively unimportant variables and structural parameters of low statistical dependability. Even with the still large number of structural equations remaining, it would be impossible to process all the calculations by traditional methods relying on human energies alone. Taking any single type of structural equations used in the model, there may be a considerable variety, depending on the country, in the constituent explanatory variables and structural parameters employed.

In setting up the model's structural parameters, recourse was taken primarily to the following statistical materials: United Nations publications:Yearbook of National Accounts Statistics; Statistical Yearbook for Asia and the Far East, Monthly Bulletin of Statistics; International Labour Organization (ILO): Yearbook of Labour Statistics; OECD Publications; National Accounts Statistics, Development Assistance, Labour Force Statistics; International Monetary Fund (IMF): Direction of Trade, A Supplement to International Financial Statistics.

In addition, use was made of statistics from the governments and central banks of the countries involved. Time series data were prepared both in terms of current market prices and constant price base, the latter being taken uniformly to represent the year 1970. As common currency units, we adopted the US dollar and also the SDR. The model's structural parameters were set up mostly on the basis of time series data for the period 1960-1973.

In setting the model's structural parameters, the ordinary least-squares method was used. However, the optimum combination of variables for a given structural equation was achieved by first running a large number of computer calculations designed to set automatically the most meaningful parameters.

In attempting to forecast the economies of the 31 countries involved, we tried to simulate growth patterns under conditions of a variety of hypothetical policy assumptions. For example, using the parameter of "governmental aid policy" (included as part of the model), various countries' target figures for official development aid (ODA) were used in taking account of actual potential for the full realization of such target figures.

The multi-nation economic model which may be written as follows;

<u>Type I</u>

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

A 2. $$f^*_o = \bar{z}_c\, [\alpha + \beta\, \hat{\hat{T}}^*_o] + \bar{z}_d\, [m^* - \sum_j e^*_{ij}]$$

where

$$\bar{z}_c = 0 ,\ \bar{z}_d = 1 \text{ (for Hong Kong and Singapore)}$$

$$\bar{z}_c = 1 ,\ \bar{z}_d = 0 \text{ (for all other countries)}$$

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

A 4. $$g^* = \alpha + \beta\, r^*$$

A 5. $$r^* = \alpha + \beta\, x^*_{-1}$$

L 6. $$\Delta s^*_p = W\, [\, \bar{z}_a \{ \alpha + \beta\, y^*_{c-1} + \gamma\, e^*_{-1} \overset{\Theta}{+} \delta\, \bar{i}_{-1} \overset{\Theta}{+} \varepsilon\, [\bar{o}_{da} + \Delta\bar{s}_{op}]_{-1} \} + \bar{z}_b \{ \alpha + \beta\, x^*_{-1} + \gamma\, [\sum_i \bar{o}_{da(ij)} + \sum_i \Delta\bar{s}_{op(ij)}]_{-1} + \delta\, e^*_{-1} \overset{\Theta}{+} \varepsilon\, \bar{i}_{-1} \}]$$

where

$$\bar{z}_a = 1 ,\ \bar{z}_b = 0 \text{ (for ACs)}$$

$$\bar{z}_a = 0 ,\ \bar{z}_b = 1 \text{ (for LDCs)}$$

A 7. $\Delta s^*_h = \alpha + \beta\, x^* \overset{\Theta}{+} \gamma\, p_{h-1} \overset{\Theta}{+} \delta\, \bar{I}_{-1}$

A 8. $\Delta s^*_i = \alpha + \beta\, x^* \overset{\Theta}{+} \gamma\, \bar{I}_{-1}$

L 9. $y^*_c = \alpha + \beta\, x^* \overset{\Theta}{+} \gamma\, \bar{I}_{-1}$

L 10. $\omega = \alpha + \beta\, p_{c-1} + \gamma\, (\frac{x^*}{l}) \overset{\Theta}{+} \delta\, \bar{u}_{-1}$

L 11. $p_c = \alpha + \beta\, p_{w-1} + \gamma\, \omega + \delta\, p_{m-1}$

A 12. $p_{cg} = \alpha + \beta\, p_{w-1} + \gamma\, \omega$

A 13. $p_i = \alpha + \beta\, p_w + \gamma\, (\frac{\Delta s^*_p}{x^*})$

A 14. $p_h = \alpha + \beta\, p_i + \gamma\, \omega$

L 15. $p_w = \alpha + \beta\, p_{m-1} + \gamma\, [\frac{\omega}{(\frac{x^*}{l})}] + \delta\, (\frac{x}{x^*})_{-1} + \varepsilon\, \bar{I}_{v-1}$

L 16. $p_e = \alpha + \beta\, p_{w-1} + \gamma\, \bar{I}_{qw-1} + \delta\, (\frac{x}{x^*})_{-1} + \varepsilon\, p_{m-1}$

A 17. $$(\frac{x^*}{l}) = \Psi\, [\, \bar{z}_a\, \{\, \alpha + \beta\, (\frac{\sum_{t}^{-4} \Delta s^*_p}{l}) + \gamma\, (\frac{\sum_{t}^{-4} r^*_d}{l}) + \delta\, \bar{q}\, \} + \bar{z}_b\, \{\, \alpha + \beta\, (\frac{\sum_{t}^{-4} \Delta s^*_p}{l}) + \gamma\, (\frac{\sum_{t}^{-4} \bar{r}^*_{dm}}{l})\, \}\,]$$

A 18. $r^*_d = \alpha + \beta\, x^*_{-1}$

A 19. $1 = (1 - \bar{u})\, \bar{I}_{cs}$

A 20. $p = \frac{x}{x^*}$

A 21. $e^* = \sum_j e^*_{(ij)} + f^*_o$

A 22. $m^* = \sum_j e^*_{(ij)} + m^*_o + \bar{m}^*_E$

A 23. $p_m = \{ \sum_j [p_{e(i)} \cdot e^*_{(ij)}] + \hat{\bar{p}}_{eo} \cdot m^*_o + \hat{\bar{p}}_{eE} \cdot \bar{m}^*_E \} / [\sum_j e^*_{(ij)} + m^*_o + \bar{m}^*_E]$

A 24. $e = p_e \cdot e^*$

A 25. $m = p_m \cdot m^*$

A 26. $c = p_c \cdot c^*$

A 27. $g = p_{cg} \cdot g^*$

A 28. $\Delta s_p = p_i \cdot \Delta s^* p$

A 29. $\Delta s_h = p_h \cdot \Delta s^*_h$

A 30. $\Delta s_i = p_w \cdot \Delta s^*_i$

A 31. $x = e - m + c + g + \Delta s_p + \Delta s_h + \Delta s_i$

A 32. $c^* = x^* - e^* + m^* - g^* - \Delta s^*_p - \Delta s^*_h - \Delta s^*_i$

L 33. $b = e - m + \bar{j}$

L 34. $\bar{o}_{da} = \pi \cdot x^*$

L 35. $\Delta \bar{s}_{op} = M \cdot x^*$

A 36. $\bar{o}_{da(ij)} = \Omega \cdot \bar{o}_{da}$

A 37. $\Delta \bar{s}_{op(ij)} = K \cdot \Delta \bar{s}_{op}$

<u>where</u>

x	:	A column vector of n element which denotes gross national product (at current market prices) of n countries within the endogenous region.
x^*	:	A column vector of n element which denotes gross national product at constant prices.
$e^*_{(ij)}$	:	An element of $e^*_{(ij)}$ 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^*	:	A column vector of n element which denotes exports of goods and services (including factor income, at constant prices).
m^*	:	A column vector of n element which denotes imports of goods and services (including factor income, at constant prices).
m	:	A column vector of n element which denotes imports of goods and services (excluding factor income, at current prices).
m^*_o	:	A column vector of n element which denotes imports of goods from all other countries (at constnat prices).
c	:	A column vector of n element which denotes private final consumption expenditure at constant prices.
c^*	:	A column vector of n element which denotes private final consumption expenditure at constant prices.
g	:	A column vector of n element which denotes government final consumption expenditure at current prices.
g^*	:	A column vector of n element which denotes government final consumption expenditure at constant prices.

r^* : A column vector of n element which denotes government current revenue at constant prices.

Δs_h : A column vector of n element which denotes housing investment at current prices.

Δs^*_h : A column vector of n element which denotes housing investment at constant prices.

Δs_p : A column vector of n element which denotes non-housing investment at current prices.

Δs^*_p : A column vector of n element which denotes non-housing investment at constant prices.

Δs_i : A column vector of n element which denotes increase in stocks including statistical errors at current prices.

Δs^*_i : A column vector of n element which denotes increase in stocks at constant prices.

r^*_d : A column vector of n element which denotes research and development expenses at constant prices.

y^*_c : A column vector of n element which denotes corporate profit at constant prices.

l : A column vector of n element which denotes employment in terms of man-hour.

$\bar{l}_{cs}$: A column vector of n element which denotes civilian labour force in terms of man-hour.

$\bar{u}$: A column vector of n element which denotes unemployment ratio.

ω : A column vector of n element which denotes average wage and salary per employee at current prices.

$\bar{i}$: A column vector of n element which denotes average interest rate on loan.

$\bar{p}$: A column vector of n element which denotes foreign exchange rate in terms of SDR.

b : A column vector of n element which denotes balance of payments.

$\bar{j}$: A column vector of n element which denotes balance of the capital accounts.

p	:	A column vector of n element which denotes implicit deflater of GNP.
$\bar{t}_m$	:	A column vector of n element which denotes rate of customs duty to total imports.
$\bar{t}_{mji}$	:	A column vector of n element which denotes country j's rate of customs duty to imports from country i.
$\bar{q}$	:	A column vector of n element which denotes high-level manpower ratio (1(01)/1)
p_c	:	A column vector of n element which denotes implicit deflater of private consumption expenditure (consumers prices index).
p_{cg}	:	A column vector of n element which denotes implicit deflater of government consumption
p_i	:	A column vector of n element which denotes implicit deflater of fixed equipment investment.
p_h	:	A column vector of n element which denotes implicit deflater of housing investment.
p_w	:	A column vector of n element which denotes implicit deflater of increase in stocks (wholesale price index).
p_e	:	A column vector of n element which denotes export price index.
p_m	:	A column vector of n element which denotes import price index.
$\bar{o}_{da}$	:	A column vector of n element which denotes each OECD, DAC country's total official development assistance (net).
$\bar{o}_{da(ij)}$	:	An element of $\bar{o}_{da(ij)}$ matrix which denotes official development assistance from DAC country i to the LDC j within the endogenous region.
$\Delta\bar{s}_{op}$	:	A column vector of n element which denotes each DAC country's overseas private investment (net) to the LDCs.
$\Delta\bar{s}_{op(ij)}$	:	An element of $\Delta\bar{s}_{op(ij)}$ matrix which denotes overseas private investment from DAC country i to the LDC j within the region.

$\bar{o}_f$	:	A column vector of n element which denotes other official financial flows from DAC country i to the LDCs (net).
$\bar{o}_{f(ij)}$	:	An element of $\bar{o}_{f(ij)}$ matrix which denotes other official financial flows from DAC country i to the LDC j within the region.
$\bar{o}_{pf}$	:	A column vector of n element which denotes other private flows (net) to the LDCs.
$\bar{o}_{pf(ij)}$	:	An element of $\bar{o}_{pf(ij)}$ matrix which denotes other private flows from DAC country i to the LDC j within the region.
$\bar{o}$	:	A column vector of n element which denotes each DAC country's total official development assistance and overseas private investment (net).
$\bar{a}_m$	:	A column vector of n element which denotes each LDC's official development assistance (net) received from multilateral agencies.
$\bar{a}_c$	:	A column vector of n element which denotes each LDC's official development assistance (net) received from centrally planned economy zone.
$\bar{m}^*_E$	:	A column vector of n element which denotes oil imports from the Middle East (except Iran).
$\bar{i}_v$	:	A column vector of n element which denotes income velocity of money.
$\bar{r}^*_{dm}$	:	A column vector of n element which denotes imports of technology.
$\hat{\bar{T}}^*_o$	:	A variable which denotes imports of all other countries at constant prices.
$\hat{\bar{p}}_{eE}$	:	A variable which denotes oil export unit price index.
$\hat{\bar{l}}_{qw}$	:	A variable which denotes international liquidity (world total).
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 the region.
B, Γ, Ξ E, F, P Z, Θ, Λ	:	A n x n matrix which denotes the coefficients of export functions from country i to country j within the 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	:	A diagonal matrix of a n x n order which denotes coefficients of a group of structural equations.

FORECAST RESULTS

The results achieved in the study, which yielded various forecasts taking 1970 as the base year and 1980 as the forecast target year, may be given roughly as follows:

1) From 1970 through 1980, the advanced industrial countries, under the influence of inflation, all show an apparent acceleration in GNP growth, but are characterized by the appearance of several countries among them whose rate of real economic growth shows a slowing trend. In particular, Japan, Italy and perhaps other countries decrease in real growth rate, although there is no considerable decrease in real growth rate for the expanded European Community as a whole, nor for the United States, Canada and Australia.

2) Because of an acceleration in the rate of real economic growth in the Asian developing nations as a group, the gap is growth rates between the "Southern" and "Northern" economies in to some extent trending toward correction. However, the gap in material standards of living, measured in absolute terms, continues to widen which causes serious North-South perplexities.

3) Those developing countries most strongly affected by the impact of the oil crisis -- eg. Republic of Korea and Taiwan -- register a temporary reduction in the growth rate for 1974, in the case of the Republic of Korea and Taiwan, previous growth rates are thereafter quickly recovered, which places those two countries as before, in a category by themselves, characterized by high growth rates in excess of 8-9 percent. In the Association of Southeast Asian

Nations' grouping (which includes some oil-producing nations who benefited from the oil crisis) growth rates average approximately 7 percent; this represents a further strengthening of the accelerating trend already seen, to some extent, in the 1960s. Oil-producing Iran enjoys a high growth rate, in excess of 10 percent. The remaining nations grouped in South and West Asia have growth rates in the 1970s which remain, as before, at less than 6 percent.

4) Among the countries involved, there is an evident trend toward growth in the various relations of mutual dependence in the economic sphere. In particular, there is a strengthening in the degree of dependence on Japan by the 15 developing countries, and critical conditions of an extremely high "degree of sensitivity" to Japanese economic policies are engendered.

5) Due to the accelerated rate of economic growth in some Asian developing countries, and to expanded markets, there is a trend toward trade expansion among the developing countries in Asia, however this is not sufficient to weaken the dependent relationships with respect to the advanced industrial countries.

6) At the same time that the interdependency of the Asian developing countries on the advanced industrial countries, in particular, on Japan, becomes stronger, their expectations with respect to Japan, their potentially largest aid-giving and trading partner, will also become stronger. This mean that Japan will be asked to make concessions in the areas of aid, trade expansion and structural readjustment in the industrial sphere.

Judging from the above forecast results, and in line with the trend toward multi-polarization in the world economy it seems probable that Japan's greatest task between now and the 1980s will be how to respond as a nation to the request from the third world.

DIRECTIONS FOR FUTURE RESEARCH

While the type of research discussed above is done with the help of the multi-nation-link economic model, using orthodox econometric methods, we think it useful to give thought to expanding and supplementing this model into a "global economic model" using systems dynamics methodology. The "world model" developed by Forrester of MIT [1] became the foundation for the Club of Rome report the Limits to Growth [2]. Because this "world model" dealt with sum total quantifications as applied to the world as a whole the model has not been effective for purposes of exposition and analysis of the North-South economic relations. Thus it remains a future task to examine and analyze the complex aspects of North-South economic relations in ways which can put to good advantage the strong points of systems dynamics.

If we can succeed in analyzing the various aspects of crises which can occur between the developing and the advanced industrial countries (including Japan), and then forecast desirable patterns of economic development which will effectively bypass such crises, it can signify a valuable contribution to improving North-South economic relations.

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APPENDIX 1: The North-South Economic Relations Table (1970)

Exports \ Imports		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Japan	0	589.7	563.3	6,015.0	24.7	156.1	64.2	127.4	550.2	192.1	277.5	183.7	37.7
2	Australia	1,253.9	0	135.2	612.4	0.5	49.7	4.1	115.9	127.8	92.6	63.4	7.1	4.6
3	Canada	762.2	193.1	0	10.575.0	8.9	184.3	20.6	150.6	371.4	179.5	268.2	169.5	10.7
4	United States	3,460.0	985.4	9,083.8	0	74.3	1,195.0	227.6	1,484.3	2,740.2	1.352.8	1,651.0	196.1	127.4
5	Austria	13.4	10.7	44.2	118.0	0	34.8	62.6	63.2	667.6	276.5	83.7	37.6	26.3
6	Belgium	85.0	27.5	46.3	696.1	67.6	0	117.5	2,298.8	2,854.1	545.7	2,251.3	90.2	44.2
7	Denmark	26.9	12.0	27.6	263.1	48.3	42.7	0	80.5	424.1	121.9	77.1	235.5	15.9
8	France	153.8	68.6	155.9	954.9	121.1	1,967.3	172.4	0	3,688.2	1,999.3	1,007.7	94.9	135.6
9	Germany, Fed. Rep. of	534.9	290.0	322.4	3,121.7	1,553.9	2,822.9	795.9	4,230.9	0	3,053.6	3,641.9	508.9	268.3
10	Italy	127.8	90.3	128.1	1,353.8	229.0	493.7	123.4	1,687.3	2,848.6	0	621.0	62.3	95.5
11	Netherlands	85.1	77.0	75.6	506.0	102.3	1,642.3	167.2	1,173.2	3,838.0	636.8	0	112.6	38.1
12	Norway	18.6	11.4	12.5	141.5	16.0	51.0	176.7	88.7	439.0	69.6	80.2	0	12.2
13	Portugal	7.9	11.0	13.2	82.2	13.4	15.2	26.1	43.0	59.8	28.8	26.4	13.6	0
14	Sweden	66.0	70.3	96.2	408.5	102.0	210.6	665.3	341.8	795.8	216.3	305.6	735,4	42.8
15	Switzerland	162.5	59.4	70.7	461.9	268.0	118.1	97.0	420.4	765.2	482.6	138.1	65.4	59.8
16	United Kingdom	354.8	830.6	691.5	2,263.0	217.0	706.3	528.5	814.1	1,207.0	575.2	906.6	417.2	212.7
17	Burma	11.5	0.3	0	0.6	0.4	0.9	4.8	1.3	6.9	1.4	1.5	1.2	0
18	Hong Kong	177.6	69.8	68.7	896.7	7.3	25.6	18.3	10.2	167.4	18.0	38.1	13.8	1.2
19	India	281.3	33.4	36.3	274.1	0.6	26.3	5.6	24.5	44.7	17.1	18.1	1.4	0
20	Indonesia	297.0	29.4	0	110.7	0	14.9	0	5.8	44.7	6.8	41.9	0	0
21	Iran	904.8	12.6	32.5	60.1	4.1	69.5	12.3	78.3	217.3	98.2	153.4	4.6	4.7
22	Korea, Rep. of	233.9	2.9	19.5	390.4	0	1.8	0	1.6	27.3	7.2	13.5	0.1	0
23	Malaysia	306.8	37.7	32.3	219.0	0	10.7	0	36.4	52.0	55.7	53.0	0	0
24	Pakistan and Bangladesh	42.6	19.3	10.0	85.0	0.4	19.4	2.0	14.5	25.9	20.6	14.9	0.8	5.8
25	Philippines	485.0	4.6	4.2	475.9	1.2	2.9	2.8	6.8	39.5	5.0	13.8	1.6	0.2
26	Singapore	118.1	52.3	18.6	172.3	0.1	7.4	6.4	31.1	44.5	22.6	23.5	7.0	2.5
27	Sri Lanka	11.2	12.1	8.7	24.2	0.1	1.1	1.0	2.3	13.7	6.6	5.8	0	0
28	Taiwan, Rep. of	215.1	20.4	50.7	567.3	0.1	7.8	1.0	0.1	70.8	12.1	30.6	0.5	0
29	Thailand	181.3	3.6	0.8	95.5	0	5.2	2.2	6.9	25.6	13.9	61.4	0.5	1.9
30	Viet-Nam (South)	4.2	0	0	1.1	0	0.1	0	5.4	0.6	0.4	0.3	0	0

Unit: Million US dollars (1970 prices)

14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
98.7	167.9	479.9	38.7	700.3	700.3	103.1	315.8	178.7	818.2	166.5	138.4	453.7	423.0	24.9	449.2	146.1
11.5	4.2	544.8	3.4	39.3	92.0	41.3	44.2	17.1	13.3	72.0	19.3	51.2	117.7	15.1	37.4	22.7
47.1	39.5	1,436.7	2.0	17.7	20.5	125.9	16.0	8.0	18.0	13.8	54.6	29.3	10.7	9.0	7.8	3.7
543.5	700.4	2,536.8	11.3	527.0	405.7	573.2	264.4	326.4	636.7	66.6	325.4	373.2	239.7	12.3	150.2	352.2
124.5	296.1	175.1	0.5	1.0	4.4	3.4	2.9	13.9	3.7	2.7	3.7	2.0	4.1	0.5	6.7	0.1
230.2	237.2	418.9	2.0	7.4	57.9	41.2	9.1	44.3	3.9	9.8	13.3	5.4	11.5	3.7	15.2	7.0
555.5	83.6	623.0	0.9	2.9	10.7	3.9	2.7	9.7	1.0	4.6	3.2	3.6	10.9	2.2	9.7	0.4
258.0	846.1	728,9	5.7	5.3	34.1	23.6	16.2	67.3	43.7	29.6	28.4	20.9	29.4	9.0	19.0	30.8
1,281.6	2.087.8	1,218.1	15.0	61.5	107.8	156.0	92.1	321.0	59.4	53.4	113.0	76.7	69.3	18.5	88.6	12.7
189.2	624.7	501.3	6.8	11.5	41.6	38.1	20.1	82.6	13.2	13.5	43.8	15.5	27.5	4.2	21.0	6.9
293.2	229.1	823.6	3.1	11.7	35.1	23.4	47.3	41.2	5.8	13.5	11.7	26.1	26.7	3.4	15.0	8.8
397.6	31.8	410.2	0.4	0.1	2.8	2.7	1.3	3.5	0.1	1.0	3.1	2.2	8.2	0.5	1.5	0.0
50.4	20.0	192.9	0	0.1	1.0	0	0.3	0.7	0.1	0.8	0.3	1.5	0.5	0.2	0.6	0.4
0	196.3	817.4	1.1	1.3	9.6	14.3	3.5	22.4	1.9	11.6	8.8	8.7	9.9	1.1	8.5	1.3
172.7	0	368.8	0.6	11.0	91.2	21.3	7.9	47.1	10.3	3.6	18.0	9.2	21.5	1.5	16.2	3.2
873.8	502.3	0	15.2	15.9	238.8	175.0	8.4	159.2	27.3	145.0	118.2	60.2	150.0	44.4	77.1	10.5
2.8	0.8	0.4	0	0.1	5.6	8.7	3.5	0	0	3.4	1.6	0.0	19.8	13.6	0.2	0
41.1	36.0	256.7	9.1	49.6	0	1.7	46.1	2.3	16.6	33.1	3.7	16.0	101.8	2.6	21.2	25.7
6.9	10.4	234.7	26.8	3.0	21.4	0	5.9	34.8	3.4	15.5	0.5	1.8	21.5	39.6	8.0	2.8
0	0	12.2	0	0	9.8	0	0	0	0	16.1	0	17.1	152.7	0	0.2	0
19.9	9.3	165.9	0	2.8	13.3	95.0	0	0	33.3	0	25.9	47.0	50.7	2.9	11.8	0.7
7.9	0	13.0	0	7.2	27.6	0.5	2.7	5.1	0	0	0	1.2	11.0	0	5.0	12.8
0	0	111.0	0	0	20.9	6.2	10.6	0	0	0	0	0	362.8	0	14.5	0
4.4	3.6	75.0	11.3	0	38.2	0.1	6.1	5.3	0.4	2.2	0	0.4	19.2	11.3	0.2	0.0
10.0	2.1	16.4	0	18.8	10.7	0.8	56.1	0	33.2	0.4	0.4	0	7.2	0	5.9	0.3
4.3	1.2	106.0	3.8	12.2	63.4	10.0	0	3.2	11.3	339.7	8.0	4.2	0	6.2	51.2	110.0
0	0.3	76.4	0.4	0	1.2	3.5	0	0	0	0.3	7.1	0	2.1	0	0.1	0
3.9	2.3	14.2	0.0	0	135.5	0.4	32.5	6.7	27.8	12.0	0.9	16.2	35.8	0.3	25.1	45.1
1.0	5.3	14.7	0.1	34.6	53.5	4.9	16.4	1.5	1.8	39.9	0.4	0.7	48.9	3.9	0	10.5
0	0.0	1.0	0	1.3	1.4	0	0	0	0.0	0	0.0	0	0.4	0	0.0	0

APPENDIX 1: The North-South Economic Relations Table (1970) (concluded)

		Sub-Total	Exports	Imports	Private Consumption	Government Consumpt.	Gross Fixed Capital Formation Non-Housing	Gross Fixed Capital Formation Housing	Increase in Stocks	Gross Domestic Product
1	Japan	14,185.1	23,133.4	20,941.0	101,594.0	16,293.9	55,250.6	14,220.6	8,986,0	198,537.5
2	Australia	3,610.4	5,636.2	5,683.1	21.329.3	4,720.6	7,899.0	1,802.2	471.7	36,800.7
3	Canada	14,754.3	17,712.6	17,712.6	48.063.7	16,190.2	14,357.1	3,586.1	140.6	85,272.7
4	United States	30,622.9	54,223.0	55,279.0	618.682.0	206,637.0	129,603.0	30,885.0	1,679.0	986,430.0
5	Austria	2,084.1	4,389.5	4,354.7	8.064.1	2,071,1	1,746,5	2,105.9	359.4	14,381.8
6	Belgium	10,251.3	12,459.7	11,670.7	15,483.1	3,589.0	4,186.8	1,471.4	344.2	25,863.5
7	Denmark	2,704.3	4,620.1	3,045.3	9,560.8	3,150.8	2,676.8	783.8	28.6	15,588.5
8	France	12,715.7	23,804.3	26,346.0	85.351.4	18,277.2	27.876.8	10,145.7	5,195.7	148.178.3
9	Germany, Fed. Rep. of	26,988.4	41.203.4	37,823.3	101,606.4	29,662.8	39.457,2	10,180.9	3,070.2	187,357.3
10	Italy	9,528.3	18,919.7	18,297.0	59.743.2	11,884.4	13,232.7	6,553.8	1,432.6	93,489.6
11	Netherlands	10,072.9	16,402.6	16,786.2	17.839.9	5,057.0	6,507.2	1,673.6	607.2	31,451.2
12	Norway	2,014.6	4,827.0	4,000.2	6.067.4	2,018.3	2,556.9	560.1	305.4	11,395.9
13	Portugal	610.6	1,532.4	1,904.8	4,653.4	890.0	910.4	157.8	-15.9	6,223.2
14	Sweden	5,204.1	8,016.8	8,204.8	18,014.1	6.984.3	5,525.9	1,609.3	958.0	32,903.7
15	Switzerland	3,973.5	7,343.6	0,953.2	11,736.6	2,321.1	3,824.8	1,414.3	165.8	19,854.0
16	United Kingdom	12.365,8	26,770.4	26,090.5	74,115.4	21.180.3	17,766.3	3,507.3	1.086.9	118.336.1
17	Burma	100.4	111.6	168.3	1,562.9	322.6	241.6	0	61.0	2,131.4
18	Hong Kong	2,179.8	2.514.5	2,903.4	2,649.2	237.1	766.7	0	30.0	3,292.1
19	India	1,200.5	2.164.7	2,151.5	40,641.5	4,936.6	8,157.3	0	277.2	54.025.9
20	Indonesia	759.2	1,261.2	1,555.9	7,920.0	861.8	1,337.1	0	0	9,824.1
21	Iran	2,131.3	2,355.1	1,633.5	6,348.5	1.864.0	2,314.2	0	0	11,248.8
22	Korea, Rep. of	792.4	1,218.0	2,052.5	5,955.3	900.4	1,796.4	280.9	174.0	8,272.4
23	Malaysia	1,330.7	1,833.7	1,715.2	2,189.3	790.6	606.5	0	58.6	3,763.4
24	Pakistan and Bangladesh	438.9	860.1	1,326.0	14,315.0	1.447.8	2,414.3	0	227,6	17,938.8
25	Philippines	1,206.0	1,220.1	1,247.3	4,366.6	525,5	1,188.6	0	150.7	6,204.2
26	Singapore	1,241.1	2,513.6	2,514.0	1,202.6	220.8	446.8	0	0	1,869.8
27	Sri Lanka	178.7	376.3	428.8	1,497.6	313.2	397.0	0	9.9	2,165.2
28	Taiwan, Rep. of	1.338.5	1.667.4	1,672.5	3,028.6	998.7	1,231.4	0	200,4	5,454.0
29	Thailand	637.2	1.081.9	1,396.0	4,379.3	742.8	1,515.4	0	150.8	6,473.8
30	Viet-Nam (South)	16.3	126.9	486.5	2,312.0	658.9	289.1	0	24.7	2,925.1

A Health Care Delivery System--of the People, by the People, for the People[1]

Irwin M. Jarett (Assisted by Gabrielle M. D'Elia)

SYNOPSIS

A health care delivery system responsive to the needs of the people requires effective citizen participation. Most efforts to involve citizens fail because there are no well defined consumer-provider roles, because there is no common agreement on the values toward which the planning should be directed, and because there is no effective mechanism of evaluation by which the citizens can hold an organization accountable.

Southern Illinois University School of Medicine has been implementing a model for involving citizens in planning a health care delivery system. The model recognizes the proprietary interests of consumers and providers, and requires the use of a common language which permits users to identify both the values toward which the planning is to be directed and the criteria by which the planning efforts can be evaluated.

INTRODUCTION

Organizational form is basic to the delivery of manufactured goods and services in our highly specialized society. Adam Smith describes the impact of division of labor in his classic example of the pin factory:

> Those ten persons, therefore, could make among them upwards of forty-eight thousand pins in a day. Each person, therefore, making a tenth part of forty-eight thousand pins, might be considered as making four thousand eight hundred pins in a day. But if they had all wrought separately and independently, and without any of them having been educated to this peculiar

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[1] This paper was originally entitled "Organizational Change and Service Delivery," and presented at the Western Conference on the Use of Mental Health Data, Sixth Annual Meeting, Newporter Inn, Newport Beach, California, October 20,1971, sponsored by Western Interstate Commission for Higher Education. It was rewritten for presentation at: The President's Committee on Health Education, January 12, 1972.

> business, they certainly could not each of them have made twenty, perhaps not one pin in a day; that is, certainly, not the two hundred and fortieth, perhaps not the four thousand eight hundredth part of what they are at present capable of performing, in consequence of a proper division and combination of their different operations [1,p.5].

Smith expands his example to include all forms of labor. He further notes that the advantages of the division of labor occur most in a society that is "improved" to facilitate the newer technology:

> In every other art and manufacture, the effects of the division of labour are similar to what they are in this very trifling one; though, in many of them, the labour can neither be so much subdivided, nor reduced to so great a simplicity of operation. The division of labour, however, so far as it can be introduced, occasions, in every art, a proportionable increase of the productive powers of labour. The separation of different trades and employments from one another, seems to have taken place, in consequence of this advantage. This separation too is generally carried furthest in those countries which enjoy the highest degree of industry and improvement; what is the work of one man in a rude state of society, being generally that of several in an improved one. In every improved society, the farmer is generally nothing but a farmer; the manufacturer, nothing but a manufacturer. The labour too which is necessary to produce any one complete manufacture, is almost always divided among a great number of hands [1,p.5].

Society has attempted to mold our social organizations to maximize the benefits from the more advanced and specialized division of labor made possible by our more sophisticated technology. In addition, the population is growing in total to such a level that it is difficult to comprehend the implications of change. The combination of the growing population and the changing technology has caused the emergence of social pressures that are much more powerful than any we have previously experienced. Our social problems seem to have reached that critical mass where social revolution is upon us.

Reich, in Greening of America, and Toffler in Future Shock, have tried to examine the causes of our social crisis. They contend that the impact of large organizations on the individual is so severe that the pressures have caused the individual to lose his ability to cope or act. According to Reich:

> Unreality is the true source of powerlessness. What we do not understand, we cannot control. And when we cannot comprehend the major forces, structures, and values that prevade our existence, they must inevitably come

> to dominate us. Thus a true definition of the American crisis would say this: <u>we no longer understand the system under which we live</u>, hence the structure has become obsolete and we have become powerless; in turn, the system has been permitted to assume unchallenged power to dominate our lives, and now rumbles along, unguided and therefore indifferent to human ends [2,p.326].

Toffler describes the individual's plight:

> It is the thesis of this book that there are discoverable limits to the amount of change that the human organism can absorb, and that by endlessly accelerating change without first determining these limits, we may submit masses of men to demands they simply cannot tolerate. We run the high risk of throwing them into that peculiar state that I have called future shock.
>
> We may define future shock as the distress, both physical and psychological, that arises from an overload of the human organism's physical adaptive systems and its decision-making processes. Put more simply, future shock is the human response to over-stimulation [3,p.362].

THE PROBLEM

...and so, the full circle has been traveled. At the onset of the Industrial Revolution, Adam Smith discussed how specialization would better meet human needs; now Toffler and Reich describe how this same specialization has resulted in such large complex organizational structures that we have lost our ability to control and to be concerned for human needs. Though Reich expects a new consciousness to emerge, Toffler sees a more involved society required if the rapid rate of change is to continue in a directed manner. Toffler suggests that the new social organizations will involve large numbers of citizens "...charged with social stock-taking, charged with defining and assigning priorities to specific social goals for the remainder of the century" [3,p.478]. He sees the need for all types of citizens to come together and work toward new "social future assemblies":

> Social future assemblies need not--and, given the rate of transience--cannot be anchored, permanent insitutions. Instead, they might take the form of ad hoc groupings, perhaps called into being at regular intervals with different representatives participating each time. Today citizens are expected to serve on juries when needed. They give a few days or a few weeks of their time for this service, recognizing that the jury system is one of the guarantees of democracy, that, even though service may be inconvenient, someone must do the job. Social future assemblies could be organized along similar lines, with a constant stream of new participants brought together for short periods to serve as

society's "consultants on the future."

> Such grass roots organism for expressing the will of large numbers of hitherto unconsulted people could become, in effect, the town halls of the future, in which millions help share their own distant destinies [3,p.478].

Unfortunately Toffler makes no mention of an evaluation system to measure the success or failure of the "social future assemblies." Without standard evaluation techniques, chaos will again result owing to the proliferation of a multitude of programs which may or may not be effective.

For the past four years, I have been involved in an experiment to build a methodology that could, in fact, permit "social future assemblies" to be formed and to operate effectively. Although the topics discussed in this paper appear to apply equally to all forms of organizations, both for-profit and not-for-profit, I will speak only to those agencies dealing in social services, such as hospitals, comprehensive health planning groups, departments of public and mental health, state government and universities.

The Federal Government has attempted to provide the foundation for "social future assemblies" by requiring a fifty-one percent lay-consumer representation on comprehensive health planning boards, regional medical program boards, and other service-oriented boards. The requirement results in citizens being asked to participate on boards where they have no technical competence and to deal with specific technical problems they are not qualified to handle. As a result, the professionals use the consumer as a rubber stamp to approve any program submitted; or the professional satisfies the board member's ego by assuring him his views have been considered; or worse, a terrible conflict emerges among the board members as some members press their own point and nothing gets done. The consumer, in many instances, finds himself in direct conflict with professionals about the specific technical details of how a program should be developed and operated. The resulting conflict has caused the destruction of many programs and, in many instances, has created such ill will between the consumers and the professionals that the likelihood of future participation appears to be slim.

Therefore, two basic problems exist: 1) the roles of the provider and the consumer have not been clearly identified, causing them to play each other's role with a devastating result; and 2) standards of evaluation have not been developed, thus the effectiveness of "social future assemblies" cannot be determined.

A POSSIBLE SOLUTION

As a result of my research in several projects, I have been able to develop a process that provides a possible solution to some of the diverse problems I have been describing. I have been working with large numbers of citizens in developing a planning model which requires citizens to identify a purpose for an organization, the objectives or statements of human needs the citizens feel should be met, and operational and programmatic goals. The citizens also develop standards of evaluation by which the organization's success is measured. In the sections that follow, I shall describe the following:

a) Basic assumptions of the research,

b) Model developed from the basic assumptions,

c) Description of the field tests, and

d) Conclusions.

There is no final answer. There is, however, a way to work among the citizens and their organizations. Citizens and professionals can establish a working role relationship among themselves if properly guided. The logic I have worked with for the past four years is called "Key Factor Analysis" [4,5,6,7].

THE BASIC ASSUMPTIONS OF THE RESEARCH

The three sociological assumptions that are basic to the key factor analysis (KFA) are:

1) Human beings are social creatures. A group of humans stranded on an island will organize to form a society.

2) Within the society, specialization will eventually begin to occur so the citizens can have their needs met in a more efficient manner. Some citizens will hunt, some will make cooking pots, others will cook and some will take care of the sick and injured.

3) The society will reserve the right to evaluate and control the results of the citizens, or group of citizens (organizations), who have specialized. The hunter who does not hunt, the potter who does not make pots, and the health care delivery system that does not take care of the sick and injured must answer to the society [5].

It was further assumed that if humans are to form "social future assemblies," a rational decision-making system that clearly establishes the roles among the citizens and the professionals in developing socially relevant organizations must be made available.

THE MODEL DEVELOPED FROM THE BASIC ASSUMPTIONS

It is from these basic assumptions that the key factor analysis model was developed. If people form societies to meet their needs, they must have some way of identifying the needs they want to see met. If they permit organizations to specialize and grow, they must have some means of forcing those organizations to meed needs. The key factor analysis model attempts to handle these considerations by giving the citizens an effective role in organizing to identify their needs and to identify the criteria of evaluation they will use to measure the success of organizations specialized to serve them. Table 1 describes

Table 1. Roles and steps in key factor analysis model.

Actors	Action
Professionals--acting as entrepreneurs*	1. Define the population to be served and the general scope of needs within which the organization will work.
Citizens (in small work groups)	2. Develop the purpose of the organization. The purpose of all organizations will be to meet some (or all) of the needs of some (or all) of the population.
Citizens (in small work groups)	3. Determine the societal needs and priorities. These needs and priorities are developed in the form of objective statements that indicate the desired end state in terms of need fulfillment with specified target dates.
Citizens and Professionals	4. Attempt to do more with less by discovering relationships among objectives; the objectives are placed into groupings that may be met by concurrent use of resources.

*While use of the term "entrepreneur" may raise questions, the concept is a way to recognize that citizen participation rarely begins without some individuals using their initiative to organize others. Howard S. Becker, in Outsiders, p. [8], maintains that "moral entrepreneurs" use their initiative and enterprise to over come public apathy and indifference to get certain kinds of legislation passed and enforced, as for example, prohibition.

Table 1 (continued).

Actors	Action
Citizens	5. Develop an evaluation system, independent of activities, based on the key factors and key indicators.
Citizens and Professionals	6. Develop the operational goals necessary to move the population toward the objectives.
Professionals	7. Develop the specific activities necessary to meet the goals.
	8. Develop the information system.

the steps in the model and identifies the roles of the citizens the professionals. A clarification of terms is necessary--everyone is a "citizen." Even the most highly skilled professional is a citizen and a member of the overall group called "citizen." When I speak of citizens throughout this paper, it is used in its broadest term. In my opinion, there never has been nor will there ever be a perfectly "representative" group of citizens. As long as "I" am not a member of a group, it cannot represent me. On the other hand, a "professional" is defined as that citizen who has been given permission by society to specialize in a particular field, and, who has prepared himself through extensive learning and experience to be skilled in that field.

The role of a professional is identified specifically and exclusively as a program developer. However, a problem area arises when groups begin developing goals. At first, the goals will be developed predominately by the professional because his understanding of the linkages between technology and the meeting of needs is greater than the consumer's. As citizens become more and more adept at making linkages, they will begin to take a more important participative role in developing goals. This change in role will be gradual and should be expected to occur over a long period of time. I will be referring to these eight steps in the model as I describe how the process has actually been put into operation.

A DESCRIPTION OF THE FIELD TESTS

Field tests have been performed at Fort Logan Mental Health Center, Denver, Colorado, and are still underway at the Department of Mental Health, Raleigh, North Carolina, and the Southern Illinois University School of Medicine, Springfield, Illinois.

These experiments were to establish a long-range planning program for the named institutions where citizen participation was formally and systematically encouraged.

The Fort Logan and North Carolina experiments utilized large numbers of work teams comprised mostly of their own employees. In both instances, there was an extensive effort made to involve large numbers of citizens from the local community; however, there was some difficulty in maintaining the citizen participation over a long period of time. Those who did remain were zealous and resourceful in working through the logic. They made significant contributions and, in many cases, "kept the pros honest."

In these two experiments, over two hundred and seventy thousand man-hours were spent by the work teams following steps 1 through 5 described in Figure 1. No record has been kept of the number of hours spent in the development of the goals and programs (steps 6 and 7). These two steps are a normal process carried on by all organizations. In both Fort Logan and North Carolina, the logic was installed as a "project"; and in both instances, the project titles and activities were dropped as the process became an integral part of the management philosophy.

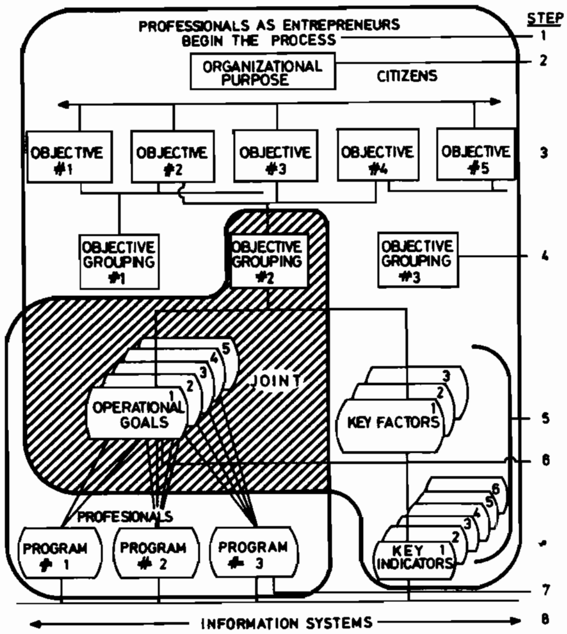

Figure 1. Key factor analysis logic diagram.

The S.I.U. research is substantially different. In the other two experiments, the internal staff support was the primary source of continuing work groups. The constituency that developed among the external lay citizens was relatively small in comparison to the total effort. However, with S.I.U. School of Medicine, citizens outside of the School provide the basis for the majority of the work that is being done. Out of the 400 participants, only 30 are from the School of Medicine.

Citizens begin to participate in the planning process by attending a two-day workshop. During the first morning, they hear a lecture which explains the logic; later they divide into small groups of 10 members or less, and try working through each step in the logic. Each group tries to agree on a purpose for the School of Medicine, a set of objectives, key factors and key indicators and some sample goals. The results are collected and documented for use in the continuing work groups.

After completing the workshop, the participants can then begin attending planning meetings to actually complete the various parts of the logic. Beginning in July 1971, several workgroups were formed to develop a purpose (step 2) and a set of objectives (step 3) for the School of Medicine. The School of Medicine has adopted the following citizen-developed statement as its purpose: "To assist the people of Central and Southern Illinois to meet their health needs."

A voluntary citizen group also selected a final list of objectives by choosing from all the objectives developed by the various groups. The School of Medicine officially adopted the 18 submitted objectives in December 1971, and these included the statements listed in Table 2. Other citizen workgroups completed the objective groupings (step 4), and the key factors and indicators (step 5) and the goals (step 6) are currently being developed.

Table 2. Objectives adapted by the Southern Illinois University School of Medicine, effective December 1971.

By____year,____%: People With Optimal Functions of Anatomic and Physiologic Systems

"Optimal" is defined as what is best under the circumstances. This objective covers the physical health of the human being. This objective was accepted with the assumption that all bodily systems are included. To develop each bodily system into a separate objective would be programming, since the caring for a particular system or the action taken to provide optimal functions of anatomic and physiologic systems.

Table 2 (continued).

By____year,____%: People Adequately Nourished

There was no dispute over the acceptance of this objective. Everyone considered food a basic human need. "Adequate" from here on in is defined as what is needed for that particular individual at that particular time.

By____year,____%: People with Adequate Rest and Relaxation

Sleep was assumed to be part of this objective. There was no disagreement on the acceptance of this objective.

By____year,____%: People with an Adequate Supply of Clean Air

"Clean" was defined as free of harmful substances.

By____year,____%: People with an Adequate Supply of Clean Water

"Clean" was again defined as free of harmful substances.

By____year,____%: People with Adequate Protection from the Physical and Biological Environment

To remain healthy, man must be protected from such things as rain, fire, blizzards, quicksand, climate, and poisonous plants.

By____year,____%: People with a Sense of Achievement

For man to maintain some degree of a positive self-concept, he must experience some feeling of personal achievement. One way to attain a sense of achievement is to pursue individual aspirations. Therefore, "people attaining their own aspirations" is a program of the objective "people with a sense of achievement."

By____year,____%: People with Adequate Self-Development

"Adequate self-development" was defined as people growing with transition from one developmental phase to another, and people who have learned age appropriate basic skills.

By____year,____%: People with a Sense of Future

People "with a sense of the future" will look to the future before acting in the present, will have a sense of their place in the universe, will have hope, will have a sense of order (rationality) in life. They will recognize the consequences of their acts.

By____year,____%: People able to Tolerate Change

People able to look at any situation as they see it.

Table 2 (continued).

By____year,____%: People with Adequate Mobility

"Mobility" includes people able to move within their own determined space at their own determined rate. Mobility includes any type of individual movement--i.e. walking across the room, driving to neighboring towns, getting promoted to a new position in the company.

By____year,____%: People Mentally Healthy

This objective was considered a composite of all other objectives in their proper balance for that particular person. Therefore, the Committee considered this objective to be of number one importance.

By____year,____%: People Experiencing Belonging

"Belonging" was defined in broad terms to include a social, psychological, or emotional sense of belonging--e.g. belonging to a family, a company, club, a past, a heritage, an institution, an ideology, etc.

By____year,____%: People Relating

Through relationships people receive appreciation, recognition, love, and friendship.

By____year,____%: People Accepting the Dignity of Man

An individual's worth is recognized by his fellow humans. "Individual worth" is respecting all people for their intrinsic (inherent) humanity.

By____year,____%: People with Adequate Personal Space

"Personal space" defined in its broadest terms means lebensraum--"space required for life, growth, or activity." (Webster's Seventh New Collegiate Dictionary.)

By____year,____%: Institutions Meeting the Needs of Humanity

"Institution" was defined as "an established law, custom, practice, system, etc." (Webster's New World Dictionary). Institutions include religion, family, economics, education, politics, law, etc.

By____year,____%: People Responsible

"Responsible" was defined as "expected or obliged to account; answerable; accountable." (Webster's New World Dictionary).

As a result of the workshops, the citizens have identified the human needs they want to see met. The purpose, "To assist the people of Central and Southern Illinois to meet their health needs," has shaped all the activities of the School of Medicine. All programs must be consistent with the purpose and must be aimed at meeting needs. Since the citizens are developing standards of evaluation based on needs, the School of Medicine is constrained by the realization that it can only claim success insofar as it fulfills its purpose.

We can already point to concrete effects of this approach. In terms of curriculum, we have identified goals for student achievement. Students will be evaluated by whether or not they achieve the goals, not by whether they take a certain number of courses. In fact, the purpose forces the School to recognize that training physicians is just one program toward meeting the health needs of the people, and that many citizens in the area may not even have a local physician, but rather may be part of a health care delivery system. With this realization, the School has added health care planning to its basic medical curriculum.

The logical model helps the School's staff to develop comprehensive approaches to meeting needs rather than to try to solve isolated problems. In cases where it must deal with problems, the School has tried to build models with wider application. We have developed a model for turning the Southern Illinois University Student Health Service into part of a comprehensive health care delivery system that is aimed at helping to meet the health needs of all the citizens of the Carbondale area.

Since the planning model stresses the most economic use of available resources in meeting needs, the School must develop linkages with existing organizations and institutions. These include linkages with area health care providers and with existing educational institutions and governmental agencies in order to develop systems of health care delivery and to institute programs for training health administrators and other allied health personnel.

The S.I.U. School of Medicine's dependence on lay citizens has provided the basis for a most interesting examination of the roles played by citizens and their social organizations. Of the many problems that have developed in the installation of the system, the most significant is the amount of time required of the lay citizens. When dealing with a diverse mixture of people from industry, labor, ethnic and other groups, it becomes most difficult to find a day and time when people can meet over an extended period of time. We have not yet been able to sort out the complex set of motives that describe why citizens would participate in the first place. Most of the citizens find the role of developing human needs to be unique and one completely foreign to them. However, we found it difficult to justify why they should spend long periods of time trying to re-discover what was discovered in North Carolina and Colorado.

CONCLUSIONS

A health care delivery system responsive to the needs of the people requires effective citizen participation. Most efforts to involve citizens fail because there are no well defined consumer and provider roles, no common values based on needs toward which planning efforts are directed, and no standards of evaluation by which the citizens can hold organizations accountable.

I have discussed a model which requires citizens to identify the basic human needs they feel must be met, and which would help organizations to plan to meet needs rather than to solve problems. This model also tries to give citizens an effective method for holding organizations accountable for their programs. The "shock" that Toffler describes is partly because citizens have lost the ability to hold organizations responsible for serving them. This model attempts to have citizens set standards for evaluation.

The absence of standards of evaluation is one of the primary reasons for the failure of planning systems. Without standards, a different evaluation system is developed for each grant, generally by the recipient. As a result, many planning deficiencies are not identified and the degree of success or failure of the program cannot be ascertained. In fact, many programs may perpetuate themselves even when they are complete failures because of the biases of the performance criteria. Often the success of a program is merely assumed and is continued on that basis alone. The assumption that any action is better than none at all is false--only those actions that create movement toward the satisfaction of a basic human need are of value. A standard evaluation system is necessary to determine performance and to allow for comparison between programs. Only with the use of standard criteria can the inadequacies of planning and of programs be isolated and the degree of success or failure measured in a meaningful way.

The third problem I mentioned was the need for distinct roles for consumers and providers, and I think that the model of the School of Medicine attempts to deal with this issue. Many of the conclusions I have reached are supported by literature and research on small groups. This research indicates that clearly defined roles (role differentiation) are necessary to the successful functioning of the group, if productivity and participation are to be increased:

> The existence of relatively unambiguous roles relating individuals in the work group to one another may actually be a positive factor in intra-group relations. The definiteness of one structure may eliminate some of the uncertainties, the pullings and haulings that result from ambiguity in role designation [9, p.74].[2]

The conclusions of this paper indicate that citizens and professionals can work together within the KFA logic to develop socially relevant organizations.

1) Citizens actively participating in the defined roles are comfortable knowing that they will not be asked to deal with the specific technological adaptations of resources. Having had the opportunity to work through the logic, the citizens recognize that the professionals can be trusted to use their judgment in linking activities to the meeting of human needs. The citizens not only recognize their right to evaluate, but also understand how to develop an evaluation system. Once this particular point is understood, citizens are more willing to take risks in the development of new programs.

2) Professionals allow the citizens to play the more active role defined, and do not feel threatened by the citizens. In fact, they are often enthused by the unique contributions of the citizens. As noted above, the roles will not remain static. As the citizens begin to understand more and more about the linkage, they will play a more active, specific and sometimes directive role in the development of goals. The citizens will require the professionals to be specific in explaining their perceived relationship between programmatic goals and objectives. This role shifting is a positive sign because, at the goal level, the long term and operational linkages can effectively be made between the citizen and the professional.

3) The strict definition of terms and the consistent use of these terms is an absolute must. If the use of the terms begins to change, the roles will also begin to change. Both citizens and professionals find a systematic and standardized approach to solving complex relationships necessary. Thus, any deviation in the use of the language or of the definitions will cause confusion and destroy the process. Once the language and the definitions are used consistently, the individuals find no constraint in their thought process, and, in fact, insist that the creative process is enhanced by the approach.

4) The exact sequence described above needs to be followed during the first cycle of the process. The logic is a deductive process and works only from the top down. During the time when the citizens are working with the professionals in steps 1 to 5 (Figure 1), there can be no slippage back to the day-to-day problems of programmatic operations. Any shift in the sequence during the first cycle will destroy the roles and cause conflict to occur as the participants argue about programs.

5) Several "mind sets" change almost from the beginning among both the citizens and professionals. Both groups recognize within a short period of time that statistics and data are no more than a status report describing the symptoms and seldom the cause. As a result, more independent and indepth analysis of both operating and social problems occurs. The amount of studying is noticeably increased, hastening the merging of the roles at the goal level. The lay citizens begin to study the particular specialty areas of the professional, and the professionals begin to research the specific fields of the lay citizens in that group. This inter-change and exchange appear to be most useful.

Both groups understand quickly that few programs have an impact on only one objective. They recognize that as a program operates it can affect many objectives and these effects must be consciously considered.

One of the more revealing discoveries the groups make is that most organizations in the social service area are organized to support the skills of the technician, rather than to meet human needs. This single recognition has caused more programs and organizations to start to change than any other one observation. The role of the professional applying a trade changes to that of a citizen working to help other citizens meet their human needs. Citizens change from antagonists to participants in a social endeavor and become willing to establish values against which professionals may develop goals and establish specific resource allocations. The roles perceived in this way prevent an organization from hiding behind technological nonsense. It forces the citizens to accept their responsibility to guide, participate with, and eventually judge the effectiveness of organizations.

The work goes on. We need to know more.

ACKNOWLEDGMENTS

The author wishes to acknowledge the valuable assistance rended by Dr. Daniel W. Rader, Assistant Commissioner of the North Carolina Department of Mental Health, and Philip Longhurst, Jr., Executive Director of Jarett, Rader and Longhurst, in developing many of the concepts presented in this article. None of the concepts would have been developed without the help of the personnel of the Department of Health Care Planning, Southern Illinois University School of Medicine; the Department of Mental Health, Raleigh, North Carolina, Eugene Hargrove, M.D., Commissioner; Fort Logan Mental Health Center, Denver, Colorado, Ethel Bonn, M.D., Director; Richard Moy, M.D., Dean Southern Illinois University School of Medicine; and most important, the help of the interested citizens of Central and Southern Illinois.

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APPENDIX A

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"Optimal" is defined as what is best under the circumstances. This objective covers the physical health of the human being. This objective was accepted with the assumption that all bodily systems are included. To develop each bodily system into a separate objective would be programming, since the caring for a particular system or the action taken to provide optimal functions of anatomic and physiologic systems.

By_____year, _____%: PEOPLE ADEQUATELY NOURISHED

There was no dispute over the acceptance of this objective. Everyone considered food a basic human need. "Adequate" from here on in is defined as what is needed for that particular individual at that particular time.

By_____year, _____%: PEOPLE WITH ADEQUATE REST AND RELAXATION

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To remain healthy, man must be protected from such things as rain, fire, blizzards, quicksand, climate, and poisonous plants.

By_____year, _____%: PEOPLE WITH A SENSE OF ACHIEVEMENT

For man to maintain some degree of a positive self-concept, he must experience some feeling of personal achievement. One way to attain a sense of achievement is to pursue individual aspirations. Therefore, "people attaining their own aspirations" is a program of the objective "people with a sense of achievement".

By_____year, _____%: **PEOPLE WITH ADEQUATE SELF-DEVELOPMENT**
"Adequate self-development" was defined as people growing with transition from one developmental phase to another, and people who have learned age-appropriate basic skills.

By_____year, _____%: PEOPLE WITH A SENSE OF FUTURE
People "with a sense of the future" will look to the future before acting in the present, will have a sense of their place in the universe, will have hope, will have a sense of order (rationality) in life. They will recognize the consequences of their acts.

By_____year, _____%: PEOPLE ABLE TO TOLERATE CHANGE
People able to look at any situation as they see it.

By_____year, _____%: PEOPLE WITH ADEQUATE MOBILITY
"Mobility" includes people able to move within their own determined space at their own determined rate. Mobility includes any type of individual movement--i.e. walking across the room, driving to neighboring towns, getting promoted to a new position in the company.

By_____year, _____%: PEOPLE MENTALLY HEALTHY
This objective was considered a composite of all other objectives in their proper balance for that particular person. Therefore, the Committee considered this objective to be of number one importance.

By_____year, _____%: PEOPLE EXPERIENCING BELONGING
"Belonging" was defined in broad terms to include a social, psychological, or emotional sense of belonging--e.g. belonging to a family, a company, club, a past, a heritage, an institution, an ideology, etc.

By_____year, _____%: PEOPLE RELATING
Through relationships people receive appreciation, recognition, love, and friendship.

By_____year, _____%: PEOPLE ACCEPTING THE DIGNITY OF MAN
An individual's worth is recognized by his fellow humans. "Individual worth" is respecting all people for their intrinsic (inherent) humanity--equalizing in unadulterating human being. This objective separates human behavior from the human being.

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"Personal space" defined in its broadest terms means lebensraum--"space required for life, growth, or activity." (Webster's Seventh and New Collegiate Dictionary).

By_____year, _____%: INSTITUTIONS MEETING THE NEEDS OF HUMANITY
"Institution" was defined as "an established law, custom, practice, system, etc." (Webster's New World Dictionary). Institutions include religion, family, economics, education, political, law, etc.

By_____year, _____%: PEOPLE RESPONSIBLE
"Responsible" was defined as "expected or obliged to account; answerable; accountable". (Webster's New World Dictionary).

A New Approach to Citizen Involvement in Education and Health Care Delivery[1]

Helen M. Petersen, Gabrielle M. D'Elia, Michael J. Schussele, and Irwin M. Jarett

INTRODUCTION

The newly established Southern Illinois University School of Medicine is faced with developing its programs in an environment which must begin to be more responsive to the existing health problems in Central and Southern Illinois. Problems such as shortages of physician manpower, lack of integrated services, poor distribution of health care services, misuse of facilities and rising medical costs are even more acute here than in most other areas of the United States. In an effort to make a significant contribution to resolving these problems, the School of Medicine has directed its efforts toward producing physicians whose education is specifically tailored to furnishing the skills, knowledge and attitudes which will prepare them for practice within a health care delivery system responsive to the needs of the consumer. In addition, to make the health care delivery system more responsive to the needs of the people being served, mechanisms for insuring consumer input into the system--in particular in the planning and evaluation phases--have been developed. The goal of this paper is to explain these mechanisms for citizen involvement (providers and consumers [1] and to describe the results. SIU has been using a planning mode [2] which permits citizens to play an ever-increasing role in planning for a health care delivery system that will meet their needs and will still hold the School Medicine accountable for its area of responsibility.

CITIZEN INVOLVEMENT

The SIU School of Medicine has distinguished itself in that the local citizenry has been responsibly involved in its planning activities--even to the extent of drafting the publicly stated purpose of the School. This involvement was accomplished through citizen participation in workshops dealing with the logic of

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[1]This paper has been presented at the First International Conference on Education in the Health Sciences, The Hague, The Netherlands, October, 1972, which was sponsored by the International Society on Education in the Health Sciences.

planning and through small group sessions in which the actual planning was accomplished.

WORKSHOPS

The primary goal of the workshops was to acquaint the participants with a planning logic which would furnish a means of productive communication between consumers and providers during the subsequent planning sessions. During the past eighteen months, 517 citizens from Central and Southern Illinois have spent over 133,800 hours in assisting the Medical School in its planning. The School conducted fifteen workshops where they were introduced to key factor analysis (KFA) through a lecture format which covered such topics as the necessity of planning to meet needs, the right of citizens to hold organizations accountable for meeting human needs, the need for consumer involvement in relevant planning, and the importance of having a common language for planning.[2] After this introductory session, the participants were divided into smaller groups in which they began to work through the steps in the planning logic, in order to identify a set of basic needs and to determine what the School of Medicine might do to address these basic needs.

SMALL GROUPS

After each workshop the citizens were given some alternative means for participating in the development of the actual planning structure which was adopted by the School. Citizens had the option of attending committee meetings to work on the development of the purpose of the School, the set of basic needs, the grouping of the needs expressed in terms of values, the goals to meet the needs, and the evaluation criteria. Others chose to receive the minutes of each meeting and to send in their responses by phone or mail. The final proposal of each committee was reviewed by all the citizen planners before submission to the School for approval.[3] The results of each workshop were incorporated into the workings of the small groups. The School's staff participated in the small groups as technical assistants only, providing the coordination of committees and meetings, distributing committee progress reports, and supplying technical advice about the operations of the logic. A brief description of the results of citizen involvement in each phase of the logic is given below.

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[2]For a complete listing of the dates, length and number of participants for each workshop, see Table 1 in Appendix B.

[3]For a complete listing of the committees and the number of people participating, see Table 2 in Appendix B.

1) Objectives. Fifty-four citizens worked for a period of seven months in identifying a set of basic human needs. They defined human needs as those requirements necessary for a meaningful existence over an extended period of time. These identified needs became the standards toward which all of the school of Medicine planning is directed.[4] Citizens established priorities for meeting these needs by determining what percentage of the population should have their needs met by a certain date. For example, "By 1989, 97 percent of the people in Central and Southern Illinois will be adequately nourished," became one of the long-range objectives for the School.

2) Purpose. The planning model also required the citizens to develop a statement of purpose which identified the particular set of needs of a particular population for which the School will be held accountable. The purpose developed for the SIU School of Medicine by the citizens, "To assist the people of Central and Southern Illinois to meet their health needs," represents the combined efforts of 46 people meeting for two hours three times a month for six months. When this purpose was presented to the School's policy-making committee for their approval, an immediate concensus was reached between the School and the citizens.

3) Objective Grouping. The citizens meeting bi-weekly for three months next placed the identified needs into six groups on the basis of those that could be met concurrently with the same resources.[5] By forcing the School to consider designing programs to meet more than one basic need with the same resources, the citizens feel they have a means of encouraging more comprehensive, better coordinated programs that make efficient use of scarce resources.

4) Goals. Once this level of the planning structure (needs, purpose, grouping the needs) was reached, it was possible for the School to look at its charge, its resources, its relation to other organizations, and to develop a logical progression of steps (goals) that would move the population from its current condition toward the satisfaction of needs. The goals identified by the citizens, a result of 880 man-hours over a five-month period, deal with personal medical care, health care delivery systems, citizen involvement, consumer health education and relationships between the School and other organizations. An explanation of how the

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[4]For a complete listing of these human needs see Appendix A.

[5]For a complete listing of these groups please see Appendix A.

the School is using these goals is given below.

5) Key Factors and Key Indicators. The planning model also provides citizens with a means to hold the School accountable. After working for four months and meeting once a week, the citizens identified key factors and key indicators to measure the success/failure of the School's programs in meeting human needs.[6] These key factors and key indicators are now being used in the development of the Schools's evaluation system.

6) Programs. Using the citizen-set goals as targets, the School used its special expertise to begin developing technical programs.

FIVE-YEAR PLAN

Even though citizens participated in workshops and small group activities and an evaluation of the results has been conducted,[7] all of this participation and information would have been futile had the School not responded to the people. From the School's Five-Year Plan presented to the area hospitals comes the following quotation which documents that the results of these planning sessions were responsibly incorporated into the program development of the School:[8]

> Because the perceptions of a 'layman' may differ significantly from those of medical professionals with respect to health care needs, an assessment of citizen perceptions was undertaken. A series of planning workshops was conducted. Citizens participating in the workshops were encouraged to think creatively and comprehensively. Citizens were quick to note the implicit

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[6]A complete report on the Key Factors and Key Indicators is available upon request from the Department of Health Care Planning, Southern Illinois University School of Medicine, 421 South Sixth Street, Springfield, Illinois, U.S.A. 62701.

[7]An evaluation of the workshops can be found in the following article: Ware, John and Gabrielle D'Elia, "Evaluation of Educational Workshops to Prepare Consumers and Providers for Joint Health Care Planning," presented at, and published in the Proceedings of the First International Conference on Education in the Health Sciences, October 11, 1972, The Hague, The Netherlands.

[8]A copy of the Southern Illinois University School of Medicine Five-Year Plan is available upon request from the Department of Health Care Planning, Southern Illinois University School of Medicine, 421 South Sixth Street, Springfield, Illinois, U.S.A. 62701.

relationships between the practice of medicine, the prevention of disease, and the promotion of health in its broadest sense. As a result, efforts were made to define dimensions of human existence which would serve as targets for not only medical school programs, but for other programs as well. Citizen-developed statements describe targets of performance for systems of health care delivery and related organizations. The statements, referred to as 'Terminal Goals,' attempt to establish a frame of reference to which medical shcool programs may relate.

While the breadth of citizen interest and expectation represents new demands for institutional performance and accountability, it was not envisioned by the citizen planners that the medical school would divide its energies evenly among the objectives or goal areas. Instead, the medical school would focus on areas most germane to its purpose and in keeping with its capabilities. The sections that follow are devoted to descriptions of major program developmental areas. Special emphasis is given to implementing programs in a manner that attempts to be responsive to citizen-developed goal statements while fulfilling necessary functions within programs of which the medical school is proprietor.

In developing its Five-Year Plan, the School directed its activities toward attaining the citizen-identified goals. For example, one of the goals identified deals with personal medical care. The School's major impact on personal medical care is in terms of the physician that it trains to practice in Central and Southern Illinois. By describing those skills, knowledge areas, and attitudes that a physician should have to practice effectively in this area, the School has a direction toward which to better focus its curriculum. The curriculum being developed by the School is based on sequences of goals which will provide the student with the skills necessary for him to practice most effectively in the health care delivery system of the future. Each goal is a task analysis of what the physician must do if he is to practice effectively in the health care system of the future. This analysis includes a detailed description of the conditions under which the student must perform the goal, the behavior he must exhibit and the criteria by which these performances will be successfully evaluated.

The physician in the health care organization will be making decisions about the effective use of health manpower, the geographic distributions of health resources, the relative benefits to be obtained by allocating scarce and costly medical resources to various types of patients, for example, to the terminally-ill. He will be communicating with consumer groups and with a variety of public bodies about decisions relating to the planning and delivery of health care. This does not mean that the physician will become a statistician, planner, accountant, sociologist, economist, marketing expert, and so on. However, the physician must have sufficient knowledge and skill in areas of competence other than clinical medicine to make intelligent and informed decisions when presented with properly organized data. To provide students with effective learning experiences, the School realized its responsibility in assisting the community in the development of health care delivery systems.

EVALUATION

In the past, citizens had no formal role in evaluating the effectiveness of health care systems. However, the fact that consumers have indeed been evaluating health care delivery is evidenced by less-than-enthusiastic use of the present system by certain segments of the consumer population.

One of the most important contributions of the planning logic presented in this paper is that it is designed to make explicit the criteria which citizens have been tacitly using to evaluate health care delivery. Our experience has been that these criteria always relate to whether or not the particular provider institution is effectively helping the consumer to satisfy his basic needs. For example, some of the indicators (or criteria) relate to nutrition, to the adequate physiological functioning of human beings, to mental health and to an ecologically-balanced environment. Reliable and valid measurement scales for some of these indicators have been made operational. Others may take years of extensive development to operationalize. In recognition of this, the Southern Illinois University School of Medicine has begun to develop needed measurement techniques.[9] The Department of Mental Health in North Carolina has also done extensive research during the past five years in developing evaluation methodologies [3].

The School is also in the process of resolving a number of difficulties which have long plagued evaluation procedures or have rendered them ineffective. The planning model provides answers to such questions as: by what standards should success be judged? How can the conflicts resulting from different consumer and provider interests and perceptions about medical care and health care delivery be avoided? How can criticisms that the measurements of student achievement have little relation to how the student will actually perform in the health care delivery system be removed? How can the citizens be given some effective means for holding organizations accountable? How can the results of any evaluation be removed from an isolated subject area and actually incorporated into organizational procedures which bring alterations and improvements? By using the planning model the School was able to develop an integrated evaluation procedure which provides an approach which has shown some effectiveness in dealing with these questions.

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[9] See footnote 8.

SUMMARY

This paper presented a planning model and methodology which is effective in bringing citizens together (including consumers and providers) so that the providers delivery of health services and the consumers' subsequent evaluation of these services are congruent. In addition, we have presented the results of one institution's attempts to put this model into action, the response of the citizenry, and the response of the Medical School. An important contribution of this experiment in joint planning is that it has underlined the possibility that the interest of consumers and providers can be concurrently served. Thus, it seems feasible that properly organized consumer involvement and willing providers with each of their roles defined on the basis of human needs can work together to bring about mutually desirable change.[10]

ACKNOWLEDGMENT

The authors gratefully acknowledge the suggestions of Robert E. McClure, Department of Health Care Planning, Southern Illinois University School of Medicine.

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[10]For further information the reader is referred to the Department of Mental Health, State of North Carolina, Raleigh, North Carolina, U.S.A.

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By_____year, _____%: **INSTITUTIONS MEETING THE NEEDS OF HUMANITY**
"Institution" was defined as "an established law, custom, practice, system, etc." (Webster's New World Dictionary). Institutions include religion, family, economics, education, political, law, etc.

By_____year, _____%: PEOPLE RESPONSIBLE
"Responsible" was defined as "expected or obliged to account; answerable; accountable". (Webster's New World Dictionary).

APPENDIX B

Table 1. Workshops.

Date	Number Days	Total Hours	Number Attending
December 17, 18, 19, 1970	3	24	38
February 4, 5, 6, 1971	3	24	35
February 18, 19, 20, 1971	3	24	49
April 22, 23, 24, 1971	3	24	34
May 20, 21, 22, 1971	3	24	47
July 15, 16, 1971	2	16	14
August 17, 18, 1971	2	16	31
September 29, 30, 1971	2	16	34
October 21, 22, 23, 1971	3	24	30
December 9, 10, 1971	2	16	54
January 21, 1972	1	8	24
February 3, 1972	1	8	38
May 5, 1972	1	8	31
May, 15, 1972	1	8	29
July 13, 1972	1	8	29
TOTALS	31	248	517

TOTAL MAN-HOURS: 128,216

Table 2. Small groups.

Committee	No. Months Meeting	Average Meetings Per Month	Average Hours Per Meeting	Total Man-Hours	No. People
Purpose	6	3	2	1,656	46
Objectives	7	3	2	2,268	54
Objective Grouping	3	2	2	276	23
Goals	5	4	2	880	22
Key Factor and Key Indicator	4	4	2	504	21
TOTALS	25	16	10	5,584	166

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Problems of Population Doubling: The World Food Problem[1]

Hans Linnemann

> Food is the first need of every human being--a fundamental human right. But for hundreds of millions throughout the world that need is not met and that right is denied. This is intolerable.
>
> Final Declaration of the Second World Food Congress, 1970.

AIM AND CHARACTER OF THE STUDY

The study seeks to determine--for the period from the present until the time when the world's population is expected to have doubled--what developments may occur in the various regions of the world in the field of food production and consumption. Because of the comlexity of the problem and because of the need to arrive at quantitative statements, a model has been developed which specifies the various relations and interrelations of the world food sector. The results of these projections of the future development of the agricultural and food situation will be compared with norms for food consumption. This comparison of projected value and normative value leads to an analysis of desirable policy measures. The second aim is to indicate what policy measures will be necessary to steer developments in such a way that food consumption norms could be attained--if at all.

The study focuses on food supply as a world problem; the international dimensions of the problem receive full attention. This does not imply that characteristics and policies at the national level can be bypassed; it is a matter of relative emphasis only. As the research team is located in one of the rich countries, the question naturally arose: what can the rich countries do about the world food problem? Thus, the relationships between major groups of countries and the international aspects of the food problem come to the fore in our study. A large part of the work is completed. The model has been put on the computer, and the data collection and processing are almost complete.

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[1]This paper has been presented to the Club of Rome as a Progress Report as per 31 August 1974.

Parameter estimation is well under say. Simulation runs will start in October 1974. Research work will have been completed by 1 January 1975.

THE WORLD FOOD PROBLEM

During 1974-75, the urgency of the world food problem has come to the fore--often in very dramatic ways. Adverse weather conditions in parts of Africa and Asia turned hunger into starvation for millions of our fellow men. Formerly, abundant grain reserves have dwindled away to a low of less than a month's world consumption. In the international markets, prices of major foodstuffs have skyrocketed. The same is true for major agricultural inputs such as fertilizers, pesticides, and energy. World food supply is in great danger; the precarious balance between the need for food and the capacity to produce it is now becoming clear not only to the populations of the developing world--where innumerable people knew the grim reality already--but also to those living in the affluent societies.

The undeniable symptoms of the very shaky base of world food supply, both in the short and in the long run, make it imperative for the world community to join forces to solve this issue so crucial for the survival of mankind. At the World Food Conference of November 1974, governments of all nations will consider appropriate international action. One thing is obvious: the rich and economically strong nations can and should make important contributions to a world-wide collaboration in fighting the food problem.

In terms of grain equivalents, people living in the rich countries consume about six times as much as those living in the poor countries; in terms of caloric value, per capita consumption in the rich nations is about 1.5 times the consumption level of the poor. The difference is owing to the tremendous loss of calories involved in the conversion of vegetable into animal products for human consumption.

Average per capita availability of food in the world was about 750 kg grain equivalent in 1964/66--a quanity considered adequate for man's physical requirements of food (though with much less meat than presently consumed in the rich countries). Because of the unequal distribution, half of the world's population consumed less--often much less--than this average figure. Foodstuffs are not distributed on the basis of physical or biological needs, but on the basis of purchasing power. Hence, abundance of food and even over consumption (from a physical or medical point of view) can continue to exist in the world simultaneously with malnutrition, hunger and starvation.

For several reasons, food exports from the rich and agriculturally highly productive countries to the developing countries cannot solve the world food problem. Food aid may on occasions and in the short run be an urgent necessity, but it remains a temporary solution and not a cure.

The world food problem can be solved only by stepping-up the growth rate of food production in the developing countries. And this sustained increase in agricultural output in developing countries will be possible only if more advanced agricultural technology and modern inputs become accessible to their agricultural sectors.

From the point of view of agricultural technology, it is obvious that substantial increases in output are possible. By and large, the technical conditions for realizing much higher production levels are known, and it is not too difficult to specify the required inputs in terms of water, fertilizer, equipment, energy and the like. It is true that the physical availability of all these inputs cannot be taken for granted; in particular, the availability of water and the structure of the soil impose restrictions on the output levels possible in a given climatic setting. It is also true that there is some uncertainty about possible long-term ecological drawbacks of greatly expanded agricultural production. However, it would seem that the most fundamental problem--at present and in the years to come--is to create socio-economic conditions that will stimulate and enable peasants or farmers to make use of the technical possibilities for raising production.

Production increases presuppose, first, increasing effective demand for these products. This links agricultural development to economic growth outside agriculture, to changes in the income distribution, and to the world market for agricultural products. Secondly, the producers need stable and renumerative prices at the farm level. Thus, national policies in developing countries should be introduced or strengthened that guarantee stable producers' prices, leaving the farmer a margin for investment in improved means of production and reducing the risks of agricultural activity.

Thirdly, governments will have to support as much as possible the introduction of more advanced agricultural technology by providing effective agricultural extension services, credit systems, transportation networks, and other elements of agricultural infrastructure. In fact, in a number of developing countries structural changes and sometimes very fundamental reforms are urgently needed to establish the appropriate social framework for agricultural growth.

Efforts at realizing these socio-economic conditions for more rapid growth of agricultural output are made primarily at the national level. Some international co-operation exists as well, especially in the form of technical assistance and development finance. Expansion of technical and financial co-operation is clearly needed and is well within the means of the industrialized countries. But these measures will remain inadequate and perhaps even ineffective if the organization of the world market for agricultural and food products remains unchanged.

For many years, the industrialized countries have effectively protected their agricultural sectors, thus blocking the possiblity for potentially exporting developing countries to initiate a more rapid modernization and to expand their agricultural activities on the basis of the richer countries' high levels of purchasing power. In fact, it is often felt that Western food-exporting countries have on occasion spoiled the world market for their poorer competitors by supplying foodstuffs at heavily subsidized prices. More recently, in a situation of rapidly increasing scarcity of some foodstuffs (and other raw materials) importing rich countries were able to buy what they needed--although at high prices--while some developing countries had to cut down their food imports because of the price rise. The use of such "beggar-my-neighbour" policies should be ruled out in future years.

Protection of the agricultural sector in rich countries for the sake of national interests only should be modified. In the short run, this policy should not endanger adequate food supply for importing developing countries; in the long run, it should not hamper agricultural growth in the developing world. It is neither possible nor desirable to achieve this simply by abolishing the protection of agriculture in rich countries; impossible, because none of the rich countries would be prepared to bring agricultural protection to an end. It would also be undesirable, because it is unwise to rely on the free play of market forces as the steering mechanism for the future development of world agricultural production and incomes. The solution can and should come by way of a coordinating world agricultural policy, a policy that would compel all countries to formulate their national agricultural policies with due regard to the interests of others--notably the developing countries.

ANALYSIS OF WORLD FOOD POLICIES

As explained above, the present study is policy-oriented and focuses in particular on the effects of agricultural policies (and the related trade policies) of the rich countries on food production in other parts of the world. The international division of labor in the field of agriculture--in other words the distribution of food production over countries--is in the long run decisive for the world distribution of food consumption.

Thus, in our model of world agriculture[2] government policies have been incorporated explicitly. This enables us, first to indicate probable developments in the world agricultural situation if these policies remain unchanged. In addition to this "central forecast," the study predicts the impact of policy alternatives on food production and consumption at world and regional levels. This is done with the use of simulation runs

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[2]For description of the model, see Annex.

analyzing whether and which alterations in (agricultural) policy are likely to bring the world food problem faster and nearer to a reasonable solution.

By means of these simulation runs, the consequences of a variety of agricultural policies can be assessed:

- Food aid: what are the short- and the long-term implications of large-scale food aid from the rich countries for food consumption-levels in the developing countries? To what extent will the development of food production in the developing countries be affected by massive food-aid programs?

- Reduced consumption of animal products: what contribution can a reduction in the rich countries in the consumption levels of animal products (notably meat) make to a better distribution of food in the world? How would lowering of consumption of animal products influence agricultural growth possiblities in developing countries?

- International price stabilization: what will be the positive effects of a stabilization of world market prices of major foodstuffs? The price stabilization would require from the side of the rich countries a policy of controlled exports and imports with the use of adjusting domestic production and consumption.

- Reduced price support in the rich countries: to what extent would food production and consumption in the developing countries be affected by a reduction of the price support that is given in most industrialized market economies to the agricultural producers?

- Imports of centrally-planned economies: what are the consequences for the food situation in other countries or regions if, as a result of a possible discrepancy between domestic food production and consumption in the centrally-planned economies, they are forced to import from the world market?

It is conceivable that certain restrictions on agricultural processes will have to be enforced for environmental reasons. Such restrictions might affect the use of fertilizer and pesticides, or the extension of the land area for agricultural use. Simulation runs will indicate the effects of possible government measures on this point.

In addition to the analysis of various policies in the field of agriculture itself, the consequences for food production of several possible developments outside agriculture will be analyzed:

- Rate of economic development in the non-agricultural sectors will affect production growth in agriculture. Various scenarios will be set up in the simulation runs.

- Energy prices determine to a large extent the current costs for the farmer. Again, several scenarios will be constructed for the simulation runs.

- Fertilizer costs depend on the price of energy, and of some other raw materials (for example, phosphate rock, sulphur). The implications of different fertilizer prices will be studied.

It should be added here that sensitivity analysis will be applied with respect to the relationships that are assumed to hold in the model. Parameters will be subjected to small changes in their estimated values, and the responses of the model will be observed. Of course, these parameters cannot be changed at will; they cannot be changed "by decree." Nevertheless, great sensitivity of a certain parameter might indicate relatively great effectiveness of policies indirectly aiming at a change in this parameter. Sensitivity analysis will focus on consumer behavior, on the choice of agricultural technology, on the labor outflow from agriculture, and on the relation of the domestic producers' price in poor countries to the world market price. As mentioned above, the criterion by which the various policies (and combinations of policies) will be assessed is whether the norms for food consumption in all parts of the world are attained.

Our study deals mainly with those policy measures in the field of agricultural production and trade that require international action. This is not to say that solving the world food problem does not depend on domestic government policies and attitudes as well; national and international action are clearly complementary to each other. Thus, the framework of national agricultural policies is also covered in our study. However, an even greater degree of detail than appears feasible at the moment would be required for building a world model of agriculture covering the specifics of individual country policies, in, for example, agricultural extension work, or credit systems, or credit systems, or land reform.

Planning a co-ordinated, international agriculture and food policy is essential for solving the world food problem; it is to this essential element that our study is devoted. The "free play of the market forces" has not and will not solve the world food problem. Most nations have come to realize, for some time already, that laissez-faire attitudes toward domestic agriculture and food supply lead to injustice if not to chaos; how many millions have to die from hunger and starvation before international laissez-faire will have been abolished?

Contribution to the General Discussion on Wednesday, 9 October 1974 on the Latin American World Model Developed by the Fundación Bariloche, Argentina

Manfred H. Siebker

This is not a comment on a particular item of the agenda of this symposium; it is more a reaction to a number of discussion remarks or rather to the underlying mental attitude, an attitude which manifests itself more and more in meetings of this kind. I am preoccupied with the reductionist slant that pretends that there are no unquantifiables to care about, that quality in the end always boils down to more quantity. I contend that such colorblindness may be an eyesickness as detrimental to the future development of mankind as shortsightedness undeniably is.

I therefore proposed to the Scientific Coordinator of the Symposium, Bruckmann, to examine the possibility of a discussion at the end of the Wednesday session or the Thursday morning session on "what are the factors and forces that are important for the future development of mankind and which, by their nature, escape quantification and hence the classical model approach?" Since the realization of this proposal was not feasible, Bruckmann has asked me to present a short statement expressing some of the ideas I would have advanced on such an occasion. These are as follows:

1) All future models, be they mathematically formalized systems or operational structures, are based on a spiritual and motivational background. Treating them without considering and analyzing this background, "in abstracto," is often considered the proper "scientific" and "realistic" way; to my mind this is unscientific and unrealistic, at least if "scientific" is not defined as "out of context," and "realistic" as "inhuman."

2) If one abandons what I call an "economaniac" attitude that consists of reducing the motivational structure of society to solely quantifiable values, forces come into focus (such as belonging, recognition, envy) which explain many of the "irregular" features of such down-to-earth phenomena as the energy crisis, inflation, demand reduction concomitant with price increases, changes of governmental systems.

3) "Understanding" has two meanings in the English langauge (and in others); both should be applied when dealing

with human problems. Even Nietzsche has praised "love as a cognitive tool," surprising as it may be at least at first glance. It may be added that lack of understanding is less dangerous than is misunderstanding. This can be an epistemological problem (in our era of specialization and of cultural disintegration it is a rather frequent problem) or a problem of mental attitude, of conditioned thinking. An example of an attitude-imposed misunderstanding of the "facts of life" (a misunderstanding of highly political and existential importance) is the continuous underrating of the role of symbiosis (as compared to competition, battle for life) for the evolutionary development in nature and in particular in societal and cultural systems.

4) One of the participants of this symposium has asked another individual (when the latter based a certain reasoning upon the assumption of not entirely egoistic behavior of man): "Are you another utopian?" This is not untypical. A psychopathology of anti-utopians (still to be written) could perhaps show the following internal monologue as a prototype: "Man is a wolf and, please, everybody believe I am one! Because otherwise the real wolves will bite me." The well known image of wolves in sheeps' skins may be inversed: sheep in wolves' skins have become the rule, collectively perhaps more dangerous than the biblical species. The fashionable and "virile" wolfish behavior may become imprinted by auto-suggestion; it generates an aggressive society which, at least in our highly technicalized world, cannot lead to viable long-term solutions of the "global problematique."

I appeal to all individuals working on problems of the future: open up the zipper of your nice wolf's skin pullover just a little bit more than have other people!

5) The Bariloche model has taken as the variable to be maximized (and who would blame it for that) the average life expectancy at birth, expressed in years. Actual behavior of most individuals shows, however, that other values prime over numerical life expectancy. Should we not occupy ourselves therefore at least to the same extent with the problem: what do people expect from life?

A Comparison of Models and an Ecological Model

Samir I. Ghabbour

Three different models are now being discussed: the "Limits to Growth" model, the Fundación Bariloche model, and the Mesarovic-Pestel model. The first model was a prototype; it set the example for others to follow and determined the basic approach by defining the main issues to be tackled and integrated into the model. We must remember that the other two models are perfections of the Limits to Growth model and can be considered more elaborate variations on the same theme. In this way, the Limits to Growth model has served its purpose and can be relegated to history. However, it will remain the model that has influenced the two models presented at the Symposium and at a meeting in Berlin--and perhaps it is the model that will influence other models to come.

Models are now being developed in ecology for various ecosystems, all with one and the same purpose in mind. Ecosystems, the study of which has been the subject of modeling techniques, range from desert terrestrial and aquatic ecosystems through forests to freshwater lakes and epicontinental seas. I wish to quote from the Report of the Baltic Study Group (Bolin 1973) that express how models are regarded in ecology.

> In order for a model to be useful we must remember that its aim is to describe and understand the total system quantitatively. No such model, however, can be accepted before its behaviour has been tested adequately against the real behaviour of the system with regard to both the physical processes incorporated in the model, and the overall behaviour of the system.

A model to be useful has to obey a series of rigid steps; by useful we mean a model that can be used for decision-making, that is action oriented. These steps, as used in ecological modeling, are state parameters, process studies and validation tests. Validation tests are based both on short- and long-term observations in order to adjust the model as frequently as possible to changes of immediate and latent effects. To be complete, validation tests include deliberately calculated interferences to the system, representing options of action decisions and/or inadvertent human effects or natural changes. You will excuse me for being didactic, but I feel this is necessary so as to achieve the desired marriage between social and natural sciences, because social sciences are accused of being non-experimental.

These validation tests produce results which are then compared with computer runs; they are valuable in verifying the behaviour of the model. Let me continue the quotation from Bolin:

> Such verifications and further developments of models proposed represent a long-term effort. The over-all material budget represents one important set of data that is needed in this context. Such data are obviously also needed as a basis for immediate actions that may prove necessary while awaiting a more complete understanding of the system as a whole.

In my opinion this statement is the best and most concise exposée on how modeling helps us to understand the world in which we live. The text indicates that the first task should be the collection of data for two purposes: (a) to help perfect the model (or models); and (b) to allow the decision maker to intervene with immediate action confident that his decision is based on adequate data. This has very little to do directly with the modeling activity itself; rather it is a result of it and not an initiator, an output and not an input. But we must remember that these data were collected so as to serve the modeling activity, and their structure is intimately linked to modeling.

There is still a long time to go before we have the world model. We shall see a great number of models; however, we must not be satisfied with theoretical discussions on the proposed models in meetings such as this. I do not suggest that meetings should not be held; rather that the subject of discussions be changed from the abstract merits of a model to the model's behaviour. This requires the following:

1) A definition of the groupings of nations should be finally adopted. The Meadows model takes the whole world as one unit; the Bariloche model makes four groupings; the Mesarovic-Pestel model makes ten groupings. The latter two admittedly tackle more units than the Meadows model, but there is no doubt that the ultimate unit in the world model should be the nation-state. I trust that our mathematician friends will not object to a model consisting of 150 or so units, and will develop the necessary equations. The Mesarovic-Pestel model has 100,000 equations for ten groupings. This illustrates the mammoth dimensions of the effort for arriving at a satisfactory world model.

2) [Definition of types of data should be collected, and guidelines given as to how they should be collected.] I wish to see incorporated in the model exchanges among nations measured in quantity and not in monetary value. I propose that nation-states replace species in a natural eco-system. Their exchanges replace the cycling of

matter and the flow of energy of natural ecosystems. We will be spared the effort of charting energy pathways because we can know from commercial statistics who gives what to whom and for what. What is missing is the understanding that these exchanges can be categorized into levels similar to the trophic levels of natural ecosystems, that is, producer, consumer (primary and secondary) and decomposer (and even parasite). We can simplify the model (if simplification does not blur out important details) as follows: (a) primary producers consisting of Third World nations made up of three sub-groups--pro-western, non-aligned, and pro-socialist; (b) primary consumers consisting of rich developed nations and made up of sub-groups--Western Europe, Eastern Europe, and Japan; (c) secondary consumers consisting of superpowers and made up of two units--the USA and the USSR; and finally (d) decomposers and parasites made up of warring nations which change with time.

3) Validation by testing the model's behaviour against the real behaviour in terms of international exchanges and in undesigned changes.

If we go into some detail and start with the units of study, we see that the Meadows model is unitary--it takes the whole world as one unit; the Bariloche and Mesarovic-Pestel models went one step in the right direction by regionalization. Unfortunately, regionalization is a geographic approach depending on location and not on relation. It groups together varieties of nations differing in functions. What determines the role of a nation in world ecology is not its location but its exchanges with other nations governed by its complement of natural resources. Admittedly, this complement is in turn governed by geographical position; it is here that position is important, that is, not being situated in this or that continent. An example is Cuba. Should Cuba be grouped with the rest of Latin America when we come to consider international exchanges of raw materials and manufactured goods?

It may be a task beyond the capacity of present-day computers to handle the relationships and exchanges of 150 nations. For the present it is sufficient to consider groups of nations based upon function and not on position. The following eight groups are logically organized: three goups of primary producers; two groups of primary consumers; two superpowers; and probably one additional group of destructive/parasitic states.

What exchanges should we consider? From an ecological perspective the two main categories are matter and energy. For the purpose of a world model matter may be divided into life-supporting and industrial. Life-supporting matter may be subdivided into organic (for example, proteins) and inorganic (nitrates, phosphates); industrial matter includes minerals such as iron and copper. Energy is divided into fossil energy from oil and coal, and incoming energy from the sun. Solar energy must be utilized effectively if we are to meet our great demand for energy. In this connection we have only to think of the vast sun-lit Sahara which is not being utilized.

The element of international monetary exchanges should also be considered. It can never correct or rectify gaps in recycling of matter. The economics of international relations are a corollary to the world's way of handling its natural resources.

Once a model is developed as described above, it must be tested against the real behaviour of the world's nations before it can be accepted.

Annex

SUMMARY OUTLINE OF THE MODEL

It is possible to give only a brief picture of the model in a few pages. An adequate description requires a longer treatment; a research volume is scheduled for publication before mid-1975.

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 as is population growth.

The functioning of the agricultural sector is different in different economies. The model distinguishes three types of economies:

a) Rich, industrialized market economies;

b) Developing countries; and

c) Centrally-planned economies.

The distinction between a) and b) is based on the share of gross value added in the agricultural sector in gross domestic product.

Only one food crop is distinguished: "consumable protein." All food production and consumption is converted, using appropriate weights, into consumable protein of vegetable origin. Production from non-agricultural sources (for example fish) is estimated exogenously. Plants which are cultivated for non-food purposes are aggregated on the basis of content of vegetable protein; it is assumed that in each country the cultivation of food and non-food plants takes place in a constant ratio.

The model explains the development of production and consumption of "consumable protein" by population growth in and outside agriculture, economic development outside the agricultural sector, and the prices of means of production and final products in agriculture. In the rich market economies and in developing countries, yearly decisions regarding the employment of means of production are made on the basis of the quantity of labor (which is considered in the short run as given) and the prices of the means of production and the final product. In the rich market economies the latter is fixed by government on the basis of a desired parity between agricultural and urban incomes. It is assumed that in developing countries prices are determined by free market forces.

It has been assumed that the agricultural sector compares its standard of living with that of the non-agricultural sector and therefore tries to aim at achieving the purchasing power of the non-agricultural sector. As long as this does not seem attainable there is an effort toward the highest attainable. This is the driving force behind production decisions. Based on production decisions, means of production are employed which--given natural conditions--lead to a yield. The price of this final product, together with the costs, determine agricultural income. This income makes consumption possible in the agricultural sector (that is of food). Non-agricultural income determines the demand for food by the non-agricultural sector. As agricultural income deviates more strongly from non-agricultural income, inclination to leave the agricultural sector will increase. The producers that decide to stay consider their labor and that of their families as a fixed means of production.

In centrally-planned economies, decisions on production are made by government on the basis of material targets, not on the basis of prices. It is assumed that centrally-planned countries strive for self-sufficiency in food supply. Labor is attracted from the agricultural sector only when it is needed in non-agricultural sectors.

The model uses period analysis, with a time period of one year. The agricultural growing process is assumed to take exactly one year. Hence, the farmer's production decisions of period t determine the production of period t + 1.

In the industrialized market economies, an important variable taken into account by the farmer is the price guaranteed to him by the government (on the base of the desired parity income). At this government-determined price, however, markets will not usually be cleared, and export or import will take place. The economic position of the industrialized market economies is assumed to be strong enough to buy or to sell on the world market their (combined) shortage or surplus of food produce. The same holds for the centrally-planned economies, in so far as exact self-sufficiency would not be realized.

The balance between production and consumption in the industrialized market-economy and centrally-planned countries, corrected for possible changes in world stocks, gives net supply or demand of agricultural products on the world market. This supply or demand together with net supply of agricultural sectors in developing countries determine total supply on the world market. In an iteration procedure a world market price is calculated which would make in developing countries total non-agricultural consumption equal to supply. It is initially assumed that the domestic price in each developing country is a monotonic function of the world market price, as the economic position of these countries is not strong enough to disregard world market developments. This "equilibrium" price level plays a part in the decisions for next year's production.

As agricultural production is a process only partly controlled by man, the model incorporates the conditions and possibilities dictated by nature. First, an absolute upper limit is imposed on food plant production. This maximum output depends on the area suitable (or potentially suitable) for agricultural use, and on the maximum attainable yield per unit or area. The latter variable is determined by such natural conditions for plant growth as intensity of solar energy, velocity of the photosynthesis process, quantity of water available, temperature, and characteristics of the soil. Secondly, a technically-given relation links the quantity of harvested product to the quantity of plant nutrients required. This function explicitly gives the demand for N, P and K (to be provided by fertilizer or by organic material) on each production level. Thirdly, another technical relation describes the connection between the level of production per hectare (and the related demand for fertilizer) and all other inputs (production factors) per hectare, given the upper limit of production per hectare. Crucial for this relation is the assumption of diminishing marginal productivity of this input mix per unit or area. The hypothesis is that the level of production per hectare is strongly related to the availability of labor and labor-substituting capital (the operating-capacity) per unit of acreage.

Environmental constraints are difficult to establish. In the model, part of the potential agricultural area is reserved for natural vegetation. An upper limit on consumption of agricultural produce per hectare of land may be introduced, as nature cannot absorb quantities of organic waste surpassing certain levels. Restrictions on fertilizer use per hectare may be introduced exogenously. Fertilizer availability and prices are dealt with exogenously; the same is true for energy prices.

Appendix A

Agenda

Monday, 7 October		
9:00-10:30	Registration (Hotel Gutenbrunn, Baden, Austria)	
Session I Chairman: T.C.Koopmans		
10:30-10:45	Welcoming Address and Introduction to IIASA	Koopmans
10:45-11:25	Introduction and Basic Assumptions of the Model	Herrera
11:25-12:15	General Structure of the Model	Scolnik
12:15-12:45	Discussion	Sint (Rapporteur)
Session II Chairman: H.Swain		
14:30-15:15	The Functioning of the Model and the Demographic Model	Scolnik
15:15-16:00	Urbanization and Housing	Mossovich
16:00-16:30	Discussion	Bernardini (Rapporteur)
Tuesday, 8 October		
Session III Chairman: R. Levien		
9:00-10:00	Non-Renewable Natural Resources and Pollution Methods	Herrera

10:15-11:15	The Long-Term Evolution of the Prices of Energy	Suarez
11:15-12:15	Discussion	Fleissner (Rapporteur)

Session IV
Chairman: H.Knop

14:00-15:00	Food Model	Gallopin
15:15-16:15	Latin American World Model: Theoretical Structure and Economic Sector	Chichilnisky
16:15-17:30	Discussion	Blaas (Rapporteur)
Evening Session	Informal Discussion of Methodology	Rabar (Rapporteur)

Wednesday, 9 October

Session V
Chairman: V.Sokolov

9:00-10:15	Education Model	Brest
10:30-10:45	Special Report	Bruckmann Chichilnisky Scolnik
10:45-12:30	Discussion	Nordhaus (Rapporteur)

Session VI
Chairman: G.Bruckmann

14:00-15:00	Project CRISIS Forecasting Work at the Science Policy Research Unit	Curnow Clark
15:00-15:30	Global Modelling in Relation to the Developing Countries	Iyengar

15:45-16:45	Non-Economic and Economic Factors in Societal Development: The General Production Function	Gaspari Millendorfer
16:45-17:30	Modelling Resource Problems	Roberts

Thursday, 10 October

Session VII
Chairman: G.Bruckmann

9:00-9:15	IRADES	Masini
9:15-10:30	Reallocation of the World Industry	Kaya Ishikawa
10:45-11:00	On a Multi-Nation Link Economic Model	Onishi
11:00-12:00	A Health Care Delivery System of the People, by the People, for the People	Jarett
12:00-13:00	Meeting with the Press	

Session VIII
Chairman: G.Bruckmann

14:45-16:50	Problems of Population Doubling: The World Food Problem	Linnemann
16:50-17:00	Contribution of the General Discussion of Wednesday, 9 October	Siebker
17:00-17:30	A Comparison of Models and an Ecological Model	Ghabbour
17:30-17:45	Concluding Remarks	Bruckmann

Appendix B
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