200 J
MIT -
Analog study

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CENTER FOR INTERNATIONAL STUDIES
50 MEMORIAL DRIVE
CAMBRIDGE 39, MASSACHUSETTS

July 15, 1959

	LCD JUL 21 59	LCD	7/27/59

Dr. Leland C. DeVinney
Associate Director
The Social Sciences
The Rockefeller Foundation
49 West 49th Street
New York, New York

SEP 11 1959

7/9/59

Dear Dr. DeVinney:

I understand that just before he left for Africa Professor Millikan reported to you by telephone on the status of our computer study of some of the problems of initiating economic development. The enclosed report fills out the picture of our progress and difficulties over the past year, and of our preliminary explorations of the digital computer technique.

1 attached
2 filed separately

Since the report was written, further explorations have tended to confirm the apparent suitability of this approach for our study. The work of the group is now concentrated entirely on reformulating the system for this technique. We have now simulated most of the sectors separately and will soon be combining them, first into a partial model and then into the complete system. At that point--we hope by the end of next month--results, in the form of economic histories for hypothetical cases, will start to flow from the machine, ready for interpretation and analysis. By that time we should have a fairly good idea of how much longer it will take to complete the study.

When some of the machine results are available, we would be happy to show them to you and explain what they represent and how they will be analyzed. Meanwhile, if you would care to see any of the results of our preliminary explorations, I would be glad to send you a sample.

Very truly yours,

Edward P. Holland

Edward P. Holland

EPH:pec
Enclosures 3

PROGRESS REPORT, JUNE 1959

on

THE COMPUTER STUDY OF ECONOMIC TAKEOFF PROBLEMS

Edward P. Holland

Center for International Studies
Massachusetts Institute of Technology
Cambridge, Massachusetts

CONTENTS

APPENDIX

SUMMARY

Aided by a grant from the Rockefeller Foundation, the Center for International Studies in 1958 undertook a study of some of the dynamic economic problems involved in starting the economic development process (the "Takeoff") using the technique of simulation by means of electrical and electro-mechanical analog equipment. The main objective of the study is to compare the effectiveness, in an underdeveloped economy, of different kinds of economic policies and programs intended to promote continuing growth of real income while avoiding undesirable side effects. To insure relevance to some actual problems, the principal model to be studied has been patterned on the economy of India. This model has now been completely formulated, statistics on the Indian economy have been carefully studied to determine suitable values of parameters, and the program of investigation has been mapped out.

Simulation of the model with the analog equipment was attempted and a great deal of effort was expended in trying to make the simulation work. In principle, this still looks like a very suitable technique for the purpose, given sufficiently reliable equipment. However, the equipment with which this study was attempted had not been kept in first-class condition, and the staff and maintenance crew were unable to cope with the trouble-shooting problems for

such a complex economic-system model as we were trying to study. As described more fully below, these conditions led to the abandonment of the analog simulation.

Some preliminary work has since been done to explore the feasibility of carrying out this study by the technique of numerical solution, using the I.B.M. 704 digital computer at the M.I.T. Computation Center. By virtue of recently-developed programming techniques, this approach now seems much more feasible than was foreseen a year ago, and it is now planned that the study will be completed by this means. Much of the preparatory work on the model formulation, choice of numerical values, and planning of the investigation is applicable and can be used to good advantage with the new technique. In addition, the earlier attempt was excellent training for the people involved, and the partial solutions obtained have thrown useful light on the nature of some of the processes.

Substitution of a different computer technique has not altered the basic approach to the study--trial and comparison of many particular cases. This is apparently the only way that theoretical analysis can be brought to bear on some of the complex dynamic problems actually encountered in initiating economic development. Improvements in the application of theory, such as this study should yield, are urgently needed for policy guidance.

OBJECTIVES AND METHOD OF STUDY

The makers of economic policy for underdeveloped countries have to make decisions influencing--among other things--overall investment levels, the sectoral pattern of investment, control of imported consumers' goods, and imports of capital equipment. In making their decisions they are presumably trying to induce their economies to "take off" into a self-sustaining process of growth. Whether their decisions are actually effective toward this goal, however, they cannot tell by watching the immediate consequences, which often take the form of crises in the balance of payments, inflation, and distortions in the goods and factor price patterns. What to do in such circumstances must be decided on the basis of some sort of theory (explicit or intuitive), for policies based solely on alleviating the short-run difficulties will probably not lead to long-run progress. Thus there is a need for theoretical study of the problem as a whole.

The application of economic theory to problems of underdeveloped countries is obstructed by the complexity and the dynamic character of such problems. In any situation many different economic relationships seem to be important simultaneously, and some of the significant relationships are nonlinear, or have important time-profile characteristics. These complexities and dynamic factors have been recognized and discussed in descriptions

of the problems, but their combined consequences cannot be evaluated by discussion. On the other hand, it has not been possible to deal with them adequately by direct mathematical analysis; too much simplification has been required before mathematical models could be made directly soluble.

The present study is an attempt to by-pass some of these obstacles to theoretical treatment by comparing large numbers of time histories generated under various conditions with a model too complex for general solution. The model, which has been formulated on the pattern of India, represents production of several kinds of goods, all with flexible prices and with output capacities limited by previous capital accumulation. Income, consumers' preferences, and foreign prices interact dynamically with the producing sectors. The level and pattern of investment are continuously affected by profits, by capital goods costs, and by anti-inflation policy. Investment in each sector has delayed effects on capacity. Temporary bottlenecks, time-distributed effects, and other realistic features are included, which would make the model intractable for conventional mathematical analysis. The model is described in more detail in the appendix, which also includes a discussion of analog and digital computer techniques and of the procedure to be used.

The technique of the study is to have the computer generate time-histories of the many dynamically inter-related variables involved in the development of the economy, repeating the process for a large number of particular cases, with various combinations of system parameters, initial conditions, external events and policy operations. Government programs will set time-schedules of minimum rates of capital formation in some sectors. Policies in response to inflation or balance-of-payments deficits may involve modifying these lower limits, enforcing upper limits, changing tariff rates, or changing the foreign exchange rate. The results will then be compared to see how different policies and different economic conditions affect the time-paths of key economic variables. Guides will be sought for deciding how much relative emphasis to give to building up food production, or consumer-goods industries, or capital-goods industries, or transportation services--whether to combat inflation by encouraging more handicraft production, more industrial manufactures, or more imports of consumer goods--whether to try to balance the foreign account by protective tariffs, encouragement of export industries, or adjustment of the exchange rate. It is not intended, or believed feasible, to try to make forecasts. The intent, rather, is to try to identify which variables are strategic ones to control, what parameters make significant differences in the results, and what

symptoms should be watched as indicators of how far to go with any policy. Insight into these matters will be useful both for assessing the relative importance of different statistical investigations and for guiding policy.

PROGRESS TO JUNE, 1959

A year ago, when the Rockefeller Foundation undertook the support of the project, a model had been formulated in general terms and some preliminary experiments had been made with the analog technique, in which parts of the model were simulated, with arbitrary values of parameters. Since then there has been significant progress in several directions, despite a serious setback in another, and the future of the program looks promising.

Refinement of the Model

Valuable work has been done in further developing the model to be studied, especially in determining realistic numerical values for the parameters. It was thought at first that some purely arbitrary numbers would be used when it came to setting up the particular cases to be run, although of course it was recognized that some limits existed on the ranges of values that could be considered realistic. Further study of parameter values led to the realization that it would be rather impractical to generalize about them and that it would be much more useful to base

the choice of numbers on a particular country. This would not mean that the model would be restricted to the parameters estimated for that country. Indeed, we still consider it very important to study the effects of changing the values assumed. However, the changes would be deviations from a model representing a particular real country rather than some imaginary one.

Since considerable work at the Center for International Studies has been devoted to studying and evaluating information on the economy of India, this country was chosen as the prototype on which the choice of parameters for the model would be based. In spite of the considerable mass of statistics available on the Indian economy, some rather careful selection and study were required to arrive at a consistent set of values. Furthermore, not surprisingly, little or no direct evidence could be found on some of the parameters. Some of these values will have to be adjusted by trial and observation until the response characteristics of the parts of the system including them seem plausible, and any significant results will have to be tested for sensitivity to errors in the estimation of these parameters.

On many of the parameters, on the other hand, relevant statistics or estimates were found and have been used to establish a basic configuration of the model. While this configuration could not be said to be the most accurate possible image of the Indian

economy, and while it is doubted that even the best available statistics are very precise, nevertheless we are sure that the configuration is enough like India to increase our understanding of the kinds of problems we plan to study as they show up in the Indian context.

In the course of studying the available statistics and evaluating the parameters, we found also that some of the assumptions made in formulating the original model in general terms could be improved upon. Thus, a number of intersectoral product demands have been added, and the form of the consumers' demand function has been altered to give a more plausible variation of the income-elasticity of demand for food. We believe that the model, as refined through this process, is now even more suitable for the study than before. The choice of basic values for all of the parameters and of alternative values for the parameters to be varied is an important accomplishment in preparation for the experimental program.

Failure of the Analog Simulation

The model was set up as planned in the analog laboratory during December, 1958 and January, 1959, and efforts were made to check it out sector by sector. Difficulties were encountered immediately, due partly to equipment malfunctioning and partly

to mistakes and poor operating procedures by some of the economists, who were not experienced in management of experimental laboratory work. The engineering support originally counted on was not forthcoming, having been diverted into equipment maintenance. The inadequacy of the provisions for management of the laboratory work and maintenance of the equipment might have been more clearly recognized and perhaps overcome in time had it not been the result of a gradual deterioration of the situation. At the time of the original project proposal and the authorization by the Rockefeller Foundation to go ahead with the project, several other groups were planning to use the analog equipment and would have contributed funds to support a sufficiently big maintenance crew and engineering staff to conduct a satisfactory operation. Gradually, one by one, these other potential users of the equipment made other plans and decided to drop out, so that the economic simulation project was left as the only user of the equipment. It would perhaps have been wise to change our plans at the time this became apparent. However, we were encouraged to believe that we could still do the job. As things eventually developed, the estimates of set-up and maintenance work required to get and keep the equipment operating properly turned out to have been optimistic, and the lack of experience on the part of the economics personnel proved to make trouble-

shooting and verification of the model considerably more difficult than they had been when the analog was used for engineering studies. We were given ample time to make a thorough attempt to overcome all these difficulties. However, it was not possible to find more qualified technicians or organize a larger operating team with adequate background. Thus, this proved to be one of those situations in which more time does not solve the problem. The effort was finally abandoned, and M.I.T. has proceeded with its plans to dismantle the analog equipment.

Some positive results from this phase of the program may be counted. We learned some worthwhile things, at least qualitatively, and perhaps quantitatively, about the characteristics of the model that we have formulated. Although we did not succeed in making the surveys of comparable economic runs that we had hoped for, we did succeed in making the model operate a few times under various special conditions. This has given us some idea of what are feasible values of those parameters for which we have no statistical basis and which therefore must be adjusted by cut-and-try to produce plausible characteristics of the sub-system in which they occur. This process of "tuning up" the initial configuration, which had been expected to be particularly awkward with a digital computer, will thus be made

somewhat easier. Another constructive result of our work with the analog equipment was that we did succeed in studying some sub-systems or sectors of the model separately even though we did not get far with the whole combination. This has increased our understanding of the components of the economic system and has helped us to visualize what sorts of situation might develop in the complete system. We have also had useful educational experience with some of the problems of program planning, and with recognizing errors in the simulation or in the formulation. Some of this operational experience is general in its application and not just limited to the analog equipment and will therefore be helpful in continuing the program.

Digital Computer Experiments

After the attempt at analog simulation was given up (early in March, 1959), we started exploring the feasibility of using an IBM 704 computer to develop solutions for some parts of the model. To do this, even for these separate sectors of the model, would have been impossible, had it not been for the cooperation of the Industrial Dynamics Group in M.I.T.'s School of Industrial Management, who made available to us a technique and a generating program which are the fruit of several years' development work on their part. (Further explanation of the technique and the meaning of "generating program" are given in

the appendix to this report.)

Our exploratory work, so far, has consisted of translating individual sectors of the model into symbols and equations of the type required by the program, and submitting them for solution with arbitrary external conditions. The conversion from continuous variables with continuous and in some cases simultaneous feedbacks to period analysis with recursive feedbacks produced some spurious instabilities which have had to be overcome by the addition of smoothing functions, each of which required some experimental "tailoring." More problems of this nature will no doubt have to be dealt with before the entire system can be run. Nevertheless, there is now no doubt that the operation can be done, and the prospects of doing it without excessive work on program development look favorable.

FUTURE PLANS

The original objective of the study, to gain insight into the problems of economic development and into the effectiveness of policies to overcome them, is still as important as ever. The failure of the analog simulation calls for the use of other methods to accomplish the original ends. It is planned, therefore, that the study will be carried out approximately as was planned before, but using the digital computer technique as a substitute for the analog.

Several months were lost in the unsuccessful analog program, and several more have gone into exploring the feasibility of the alternative digital computer technique. Thus, although definite progress has been made and is continuing in the new direction, it is obviously going to take longer to finish the study than originally planned. The target date for completing the study, including analysis and interpretation of the results and writing of final reports, has been put off to June 30, 1960. With this necessary extension of time, some further financing will be required to bring the program to a useful conclusion.

APPENDIX

THE THEORETICAL MODEL

One of the major parts of the study which has already been completed is an economic-system model, formulated and successively refined as described above, until highly suitable for studying the kinds of dynamic problems with which this program is concerned. The general structure of the model is patterned on the broad outlines of the Indian economy so that the study will have relevance to some actual current problems of underdeveloped countries, and mechanisms included in the model were chosen in the light of the kinds of problems to be studied.

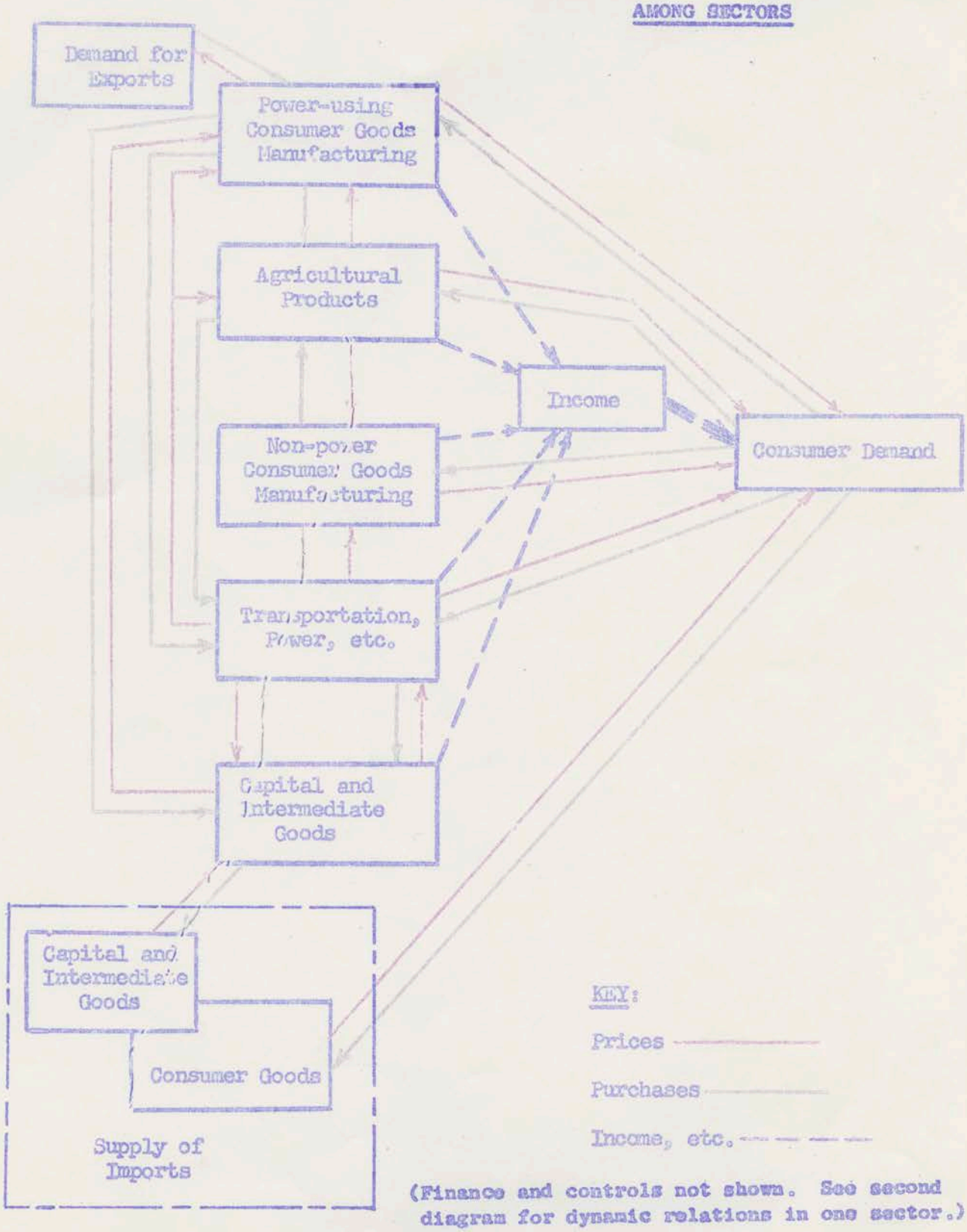
Overall structure of the model: The imaginary underdeveloped country has a rural population greater than can be utilized on its food-producing land. Thus a shortage of people is never a bottleneck in production. Population may be assumed to grow according to any arbitrary time profile. In the industrial sectors, where relocation and training of people are required, these activities are considered part of the process of capital formation.

Consumers' expenditure rates at any moment are distributed between four categories of goods and two categories of services, according to disposable income and the respective prices, interacting with a consumers' preference function. Demand for food is relatively

income-elastic and is neutral to price (unit-elastic). The other three kinds of goods are strong but not perfect substitutes for each other. They are consumer goods from power-using factories, from non-powered shops, and from foreign sources. For imported consumer goods, there is an exogenous world price (fixed or pre-programmed) subject to the exchange rate and to a tariff which may be changed by the government. The price of each domestically-produced consumer good (including food) is determined at any time by interaction of the joint demand function with three supply functions, one for each good. One of the goods is also demanded as an export to foreign markets. This demand is dependent on price and on exogenous variations. The supply functions, which involve effects of capacity changes and cost changes, are described in more detail further on. The supply-and-demand interactions are shown in the first diagram (on the following page) together with other interdependences about to be discussed.

In addition to the sectors which produce primarily for consumers, there is one in which capital goods and intermediate goods are produced for other industrial sectors. Similar goods are also available from foreign sources, subject to the exchange rate and tariffs. Transportation, power, etc., are provided by a public overhead sector. Demands from each sector for intermediate goods from other sectors are based on fixed physical-quantity

GENERAL OUTLINE OF INFORMATION FLOWS AMONG SECTORS



(Finance and controls not shown. See second diagram for dynamic relations in one sector.)

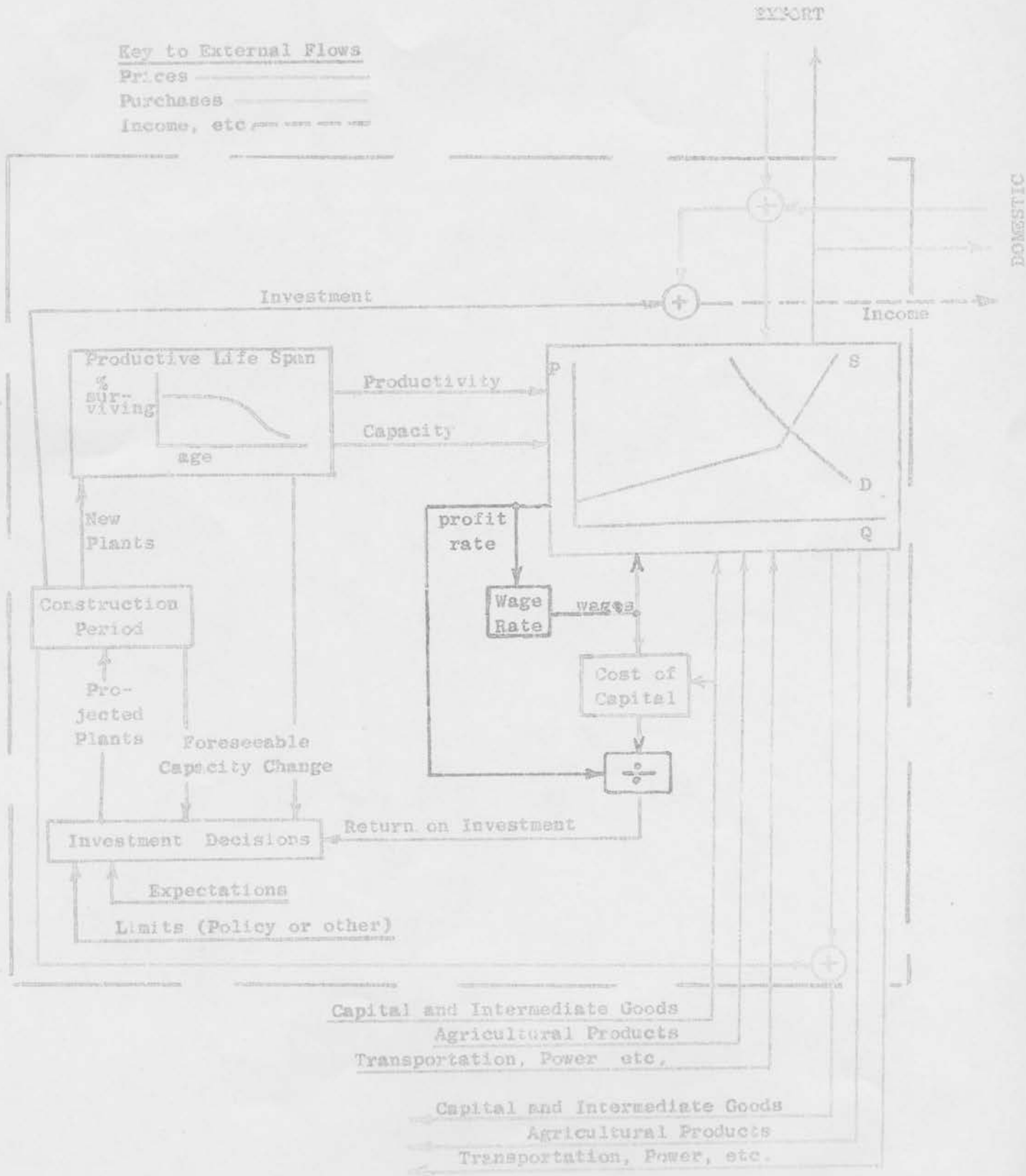
coefficients, with flexible pricing. Capital goods, also flexibly priced, are demanded in proportion to the plant capacity currently under construction in each sector.

Investment decisions are determined differently in different sectors, as described below, depending sometimes on profit rates, sometimes on government limitation or support. Investments and current production in the various domestic sectors are reflected in the gross national product, from which taxes and business savings are subtracted to ascertain disposable personal income. This information enters the demand function to determine personal savings and the expenditure on each kind of consumer good, as described initially.

Supply functions: Relationships within the power-using consumer goods industry are shown in the second diagram (next page). Supply functions for some of the other sectors are similar; others are somewhat more simple.

Consumer goods from the power-using sector are sold to both domestic and foreign consumers. The supply price depends on the costs of labor and intermediate goods. Initially, this sector has little capacity. Investments to increase capacity are motivated by expected profits, but may be limited or augmented by government action. Investment in this sector increases labor productivity as well as expanding capacity. Labor is hired or laid

PRINCIPAL RELATIONSHIPS IN POWER-USING CONSUMER GOODS MANUFACTURING SECTOR



off to match output. The wage rate index is negotiated upward when business is profitable, but never goes down. Increases in capacity, besides requiring expenditure for elastically-supplied factors, involve waiting through a significant gestation time and purchasing scarce capital goods. These may be imported (if foreign exchange permits) or purchased from the domestic capital-goods industry (if domestic capacity permits).

The capital-and-intermediate goods supply function combines a foreign supply with a domestic producing sector which is similar to the power-using consumer-goods sector. Demand is apportioned between home produced and imported goods so as to equalize the two supply prices (net, to the purchaser, including tariff or subsidy). Products of this sector are used in two ways: As inputs to the capital formation process in any sector, and as inputs to current production in some sectors.

The non-powered sector has a low capital-output ratio and static technology, with capacity limited by the stock of critical tools. Changes in capacity come (after a short wait) from investing in making more tools at a rate above or below the rate at which they wear out. In this sector there is a minimum supply price determined by wages and material prices. Hence, at low levels of demand, output may be less than capacity. High demand raises prices, yields profits, and hence stimulates private investment.

Also, wages tend to rise when profits are made. Government action may add to or limit investment.

Food output is limited by the area of land that has been cleared and by the extent of irrigation facilities. Increases in aggregate output capacity require large-scale projects, beyond the scope of individual proprietors to organize. Such private projects as are done are complementary to government programs. Hence, investment is determined by government decisions. Increased capacity follows investment after a delay. Labor is redundant and cannot be laid off, but does not receive fixed wages, being largely made up of proprietors, their dependent relatives, and people who work for a share of the output. Under these conditions no losses can be avoided by deciding not to produce, and therefore output always equals capacity, regardless of price.

Transportation, power, etc., come from a sector whose supply function is similar to that of the power-using consumer-goods industry, except that government planning and policy directly determine the construction of facilities.

Services of a professional, domestic, or personal nature, not supplied from major capital-intensive facilities, are accounted for only in terms of their money value, which is assumed to be independent of capacity and price considerations. Hence no supply function is required for this category, although it appears in demand and income.

COMPUTER TECHNIQUES

This study was previously attempted with analog equipment to simulate the model. Now it is proposed to use a digital computer. A number of factors had a bearing on this change in technique.

Analog simulation has a number of attractive features: Direct correspondence of the setup to the system being studied, ease of adjusting parameters on the basis of currently-observed results, and other conveniences. On the other hand, the analog of a system as complex as the economic model of this study uses a large number of electronic components subject to deterioration--(our setup used about 200 components, the simplest of which was equivalent to a small radio set). Not only does this require considerable routine maintenance, but it also necessitates vigilant checking and expert trouble-shooting to eliminate errors due either to incorrect connections or malfunctioning units. The magnitude of this requirement, unfortunately, was badly over-estimated, and the attempt to carry out the study by the analog technique failed for lack of sufficient properly trained people. (The laboratory had been slated for abandonment, and most of its experienced engineers and technicians had gone elsewhere. People who were unfamiliar with the idiosyncrasies of the equipment were not able to identify troubles fast enough

to meet the needs.)

MIT's IBM 704 digital computer, unlike the analog equipment, is the heart of a well-supported and active computation center, providing service to users from all departments of this institute and from several other universities. Their large and competent staff will relieve the Center for International Studies of any concern for keeping the machine working and producing solutions for whatever runs are submitted. The difficulty of coding the procedure of solution for such a complex model into a sequence of rudimentary steps that could be followed by the machine was at first thought to be a serious obstacle. However, work that has been under way for several years in MIT's School of Industrial Management has recently produced a technique that greatly eases this difficulty. Some trial solutions of a part of the model have been run by this technique, revealing a few minor problems, which have since been solved, but also indicating that it is feasible to carry out the proposed study in this way.

The operation of a digital computor differs from that of an analog in that it carries out numerical calculations instead of acting out processes, and in that the calculations are done one at a time rather than simultaneously for simultaneous events. Thus the correspondence between the economic-system model and the operations of the machine is much less direct. Basically, all operations by the machine consist of addition,

subtraction, multiplication, division, comparison, storage of information, and reference to stored information. The whole set of relations constituting the dynamic model has to be somehow reduced to a sequence of these operations performed one by one, in such order that each one uses only information that is already available. Thus, mutual relations among quantities that change with time are awkward to handle unless time lags are assumed in the relations. Analysis of processes in a dynamic system is done in terms of finite periods (which may be very short) rather than continuous variations. For each point in time, each variable must be computed from others which have already been determined for the same time or from values known from a prior time. Then the process is repeated for the next point in time, and so on. The degree of detail and explicitness of instructions ultimately required by the machine are illustrated by the following example:

Example:

Assume that one of the relations in the system is

$$w_{(t=k)} = b\left(\frac{x}{y}\right)_{(t=j)} + a$$

Where w, x, and y are variables, a and b are constants, and j and k indicate successive time steps. Assume that $x_{(j)}$, $y_{(j)}$, have been previously computed and stored in locations 100 and 101, and that b and a, (given initially) are stored in locations 102 and 103. At each time step in the computation, the following instructions must be given in order to determine w:

Meaning	Code
Clear previous calculation and introduce value of x from location 100:	CLA 100
Bring value of y from location 101, divide x by y and hold result for next operation:	FDP 101
Bring value of b from location 102, and multiply by $\frac{x}{y}$ from previous step:	FMP 102
Bring value of a from location 103, and add to result of previous steps:	FAD 103
Store answer, w, in location 104:	STO 104

A set of instructions reduced to these elements for the whole sequence of steps involved in the solution, period by period, of the equations constituting a model is called a "running program." The task of translating (or coding) the model and the operations to be done with it into a running program would be formidable for such a complex model as we are dealing with, and virtually impossible to check. (One sector, about 20 per cent of the model, which is expressed in 40 algebraic and difference equations, required 340 instructions when coded into a program.) Fortunately, however, we are able to make use of a "generating program" which has recently evolved out of several years of development work by the Industrial Dynamics group at MIT. This program, which is called "DYNAMO", is designed to handle a wide variety of dynamic economic models. With this program in the computer, the model

specification is put in the form of punched cards containing algebraic and difference equations and lists of numerical values of parameters. Within the machine, the DYNAMO program organizes the equations into a feasible sequence of computations, breaks them down into elements of machine operations, and issues the necessary detailed instructions corresponding to the more general instructions that are given by the investigator. The relation used for the example above is specified in its algebraic form:

$$w_{(t=k)} = b\left(\frac{x}{y}\right)_{(t=j)} + a$$

and the separate instructions are generated by the DYNAMO program. Thus, the generating program takes the model and problem at the level of formulation in which it is conceived by the researcher, and codes them into a running program of detailed operating instructions as required by the digital machine. This overcomes some of the difficulty that formerly made the digital-computer method less attractive than analog simulation.

The principal remaining disadvantage of the digital technique relative to the analog is not one that can cause failure of the investigation, but is a matter of less convenience and efficiency in the early stages of a study in which it is necessary to do some cut-and-try work on the model itself or on the policy variables to find out how to get a particular

desired behavior. This inconvenience results from the fact that the investigator cannot observe the results of each solution as it is computed and immediately alter the conditions for the next solution. Fortunately, a few valid solutions did come out of the analog program, and these will help to indicate appropriate values for starting the study. A convenience offsetting the inconvenience cited above is that the digital computer, unlike the analog, does not require a lengthy setup operation for a particular study, and can thus be frequently shifted from one study to another. Thus, instead of trying to carry out a whole study in one or two continuous operations, the investigators can do it in smaller parts, taking as much time as necessary to analyze some of the results before proceeding.

The major advantage of the digital computer is the reliability of the total operation. This involves not only more adequate maintenance of the equipment, but also more systematic procedures of programming and checking which make it more likely that any errors will be promptly recognized and corrected.

PROCEDURE OF STUDY

The study is based on comparison of many particular solutions, each representing the process of change in the modeled economy under a different set of conditions. In part of the study, various programs of investment allocation will be compared. Since any arbitrary investment program may lead to inflation or upset the balance of foreign payments, automatic policy mechanisms will be built in, to combat these effects by selectively modifying the program, or changing tariffs or the exchange rate according to pre-set rules. For each combination of investment plan and policy rules, results will be recorded as time-histories of output and prices in various sectors, and of wages, national product, imports, exports, etc. Many programs and policies will be planned in advance, run, and compared. In addition, results of some runs will be used as a basis for shaping new programs or modifying policy rules and trying again, in search of better results.

In another part of the study the world prices of goods exported and imported by the simulated country will vary during each solution, and alternative tariff and exchange rate policies will be explored as to their effects on the balance of payments and on development.

After either of these investigations has yielded some comparative results, the more promising areas will be re-surveyed a number of times with altered values of various structural parameters. This will indicate whether the results are sensitive to changes or errors in these parameter values. It might also show ways that such sensitivity--if it exists--can be overcome by the choice of appropriate indicators to guide policy. Major changes in structural parameters, and even qualitative changes in structure, will also be investigated, to gain understanding of the differences in the problem for different countries. The main emphasis, however, will be on the structure based on India.

Clearly, a large number of comparisons will be of interest, both comparisons between programs for a given structure, and comparisons of the behavior of different structures. It is expected that several hundred solutions will be run over the period of the study and that the job of making systematic comparisons and evaluating their significance will take many months. The potential fruits of this procedure are very great, in terms of increased understanding of the dynamic interactions involved in economic takeoff, and in terms of insights into the dynamic effects of different policies and of different indicators used to guide policy.