

INTERVIEWS: NSB

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KWT		KWT
RFE	3/20	RFE
MY	MAR 21 '58	MY
EWM		EWM
PH		PH

MAY 26, 1958

March 18, 1958

I thought MIT was going to be broken up & Jones.
 I'd be interested to hear NSB comment on E.
 If you want more info on
 AG (item 1) I can get it.

Analog study

Max F. Millikan

- Director, Center for International Studies, MIT

Donald L. M. Blackmer

- Assistant to the Director, Center for International Studies, MIT

Millikan and Blackmer came in to explore the possibilities of RF support for one or all of three separate proposals:

- 1) The Center for International Studies has been considering for some time the wisdom of adding to its program work in Latin America. Millikan will himself be a visiting lecturer at the Getulio Vargas Foundation in August, 1958, and will spend an additional two weeks in Colombia. The Center will not get into a Latin American program -- their plans are still somewhat in the formative stage -- before the Fall of 1959 or perhaps later. The reasons for this delay are that they wish to wind up their Indonesian and Italian programs, two of the three programs initially supported by FF. It will not be before summer 1959 that work under these programs will be complete. As is known from other sources, the Center will continue to expand its Indian program.

Excerpted
 as pending

Specifically they seek funds to bring a man named Alexander Ganz, now at ECLA, to spend a year at MIT to help them move into the Latin American field. Ganz, whose nationality is unknown to Millikan, has an American wife and wants to move permanently to the USA. Of the present ~~MYXX~~ staff of the Center, Paul N. Rosenstein-Rodan is probably the most knowledgeable on Latin America. This proposal would cost about \$20,000 for salary, plus one or two research assistants.

- 2) One Edward P. Holland, about 40, who was trained as an aeronautical engineer and worked well up in Boeing, decided some three or four years ago to get into some field of international work and wrote to Millikan for advice. At his own expense Holland came to see Millikan who urged him to get trained in some social science, of which economics seemed to be the obvious choice. As a consequence, Holland took a Ph.D. in economics in January, 1958, for which he prepared a rather elaborate mathematical model which is briefly described in the attached "A Proposed Analog Study of the Economic Take-Off Problem." Millikan is trying to find funds to support Holland for sixteen months to carry out the proposal set forth in the attached memorandum, at a cost, without overhead, of \$38,680.

INTERVIEWS: NSB

March 18, 1958

Max F. Millikan
Donald L. M. Blackmer

- continued

3) The Center is also getting ready to launch major work in Africa.

This grows out of Walt W. Rostow's and Millikan's concern with foreign policy problems, and what they have in mind are studies of Africa (South of the Sahara and North of the Union) which would embrace both economic and political matters, including attitudinal changes and changes in means of communication. The Center now has two people from UN assigned to MIT -- Gordon Nunsworth, an Englishman, and a Mrs. Forrest, a Pole by birth. These people are trying to assemble essentially all of the statistical, economic, and political information about this section of Africa which is extant. This is not a contract arrangement. They also have Arnold Rivkin, who was Chief of the Dependent Territories Section under the Marshall Plan. Wolfgang Stolper is again to be away from Michigan at MIT for the coming academic year.

The Center has no memorandum on Africa but will have in ten days. The primary emphasis they now have is on tying Africa to the rest of the world economically and politically. In two weeks or so they will send us the completed memorandum. This is a large undertaking running to perhaps \$300,000 dollars.

Is it significant that H. R. Haines was not mentioned?

*Don't Africa
 "tied" to
 the rest of
 the world?
 Most of
 its economy
 is export
 oriented.*

Excerpted

*Highly significant
 in approach*

Holland - Asset - Resources

Economic Development Program
D/57-36

Secundum 2

Rendall, 1957

MAY 26 1958

A PROPOSED ANALOG STUDY OF THE ECONOMIC
TAKE-OFF PROBLEM

Edward P. Holland

Indian Planners

made some bad

mistakes e.g. overland

E.D. for resources in

private sector

Don Ruscetti, maybe an Argentinean
who did a Ph.D. with Ruscetti in Econ Hist. of Argentina.

Center for International Studies
Massachusetts Institute of Technology
Cambridge, Massachusetts
December 1957

*this is purely a mechanical technique
useful if there is a promising theory to test*

*because in the eng. problems
the theory existed, it was
merely too complicated to
reckon out.*

SUMMARY

It is proposed that some of the dynamic problems of starting economic development be studied by the technique of analog simulation. This is a technique in which many separate relationships--represented by electronic circuits--are interconnected so that they operate simultaneously and dynamically. Many experiments are made in a short time to find out how different policies and different economic conditions affect the time-paths of key economic variables. The technique has proved extremely effective in a wide variety of engineering problems, and offers great potential effectiveness in economics, but has not yet been used much in this field. Here at M.I.T. there is one of the world's most versatile sets of analog equipment, capable of handling various nonlinearities and time-spread effects that are important in the economic problem. The availability of this equipment is one of the key factors in making the project possible, and presents an outstanding opportunity.

The economic problem to which this technique is to be applied is the problem of finding what kinds of policies and programs will lead to continuing growth of real income in an economy that is initially underdeveloped and stagnant. The analog will represent production of several kinds of goods, all with flexible prices and with output capacities limited by previous capital accumulation.

*this is really
rather silly*

Income, consumers' preferences, and foreign markets will be simulated. Superimposed on this system will be government incentives and restraints on investment and foreign trade. These will vary during each run to simulate development programs and adjustments in policy made in response to balance-of-payments or inflation problems. Effective policies will be found by repeated experiments. |

Groundwork already accomplished includes analog experiments on a rudiment of the model (with a second, more inclusive one currently being set up,) and detailed formulation of the analog model outlined here, so that it is known to be feasible with the equipment available at M.I.T. From this preliminary work it seems clear that carrying out the study will yield significant insights into the problem, such as cannot be obtained by other means.

a very curious, to say the least, statement.

THE ANALYTIC PROBLEM

The makers of economic policy for underdeveloped countries have to make decisions influencing--among other things--over-all 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

7

who would say to?
4

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 ^{conventional} mathematical analysis; too much simplification has been required before mathematical models could be made directly soluble.

why is this true?
These obstacles to theoretical treatment can be largely by-passed by comparing large numbers of particular solutions of a model too complex for general solution. This can be done either numerically, with a digital computer, or by the technique of analog simulation. In the project proposed here, analog simulation has been chosen because of its flexibility and convenience for feeling out relatively unexplored areas. The technique will be described in a later section, followed by an outline of the procedure of investigation. First, there are a statement of the economic problem, a review of preliminary work already done, and a description of the economic model structure. 2

THE ECONOMIC PROBLEM

In the kind of country to which this study is relevant, output per capita is initially quite low and is mainly agricultural and handicraft products. The economy operates by tradition, with no tendency to develop new products or more productive techniques. Food production is limited by the area of land cleared, and the labor force on the farms is much more than is needed for the crop that is produced.

(it usually is!)

and you right!

The problem is to find a combination of programs and policies which will lead into continuing growth of real disposable income per person. What is sought are guides 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.

The situation presents many dilemmas. For example: An import surplus is one of the chronic problems of a country trying to start development. An obvious remedy is a high tariff or a quota on imports. However, a by-product of such action is the diversion of some of the demand to the domestic market, where it adds to the inflationary pressure which is also a normal concomitant of a development effort. If home prices become inflated, the adverse balance of payments is likely to get worse instead of better. How can the proper remedy be chosen in a given case?

How, indeed!

Another example: An antidote to inflation is increased production of consumer goods, competitively priced. To increase the capacity of consumer-goods manufacturing industries requires making investment expenditures, which increase demand right away, while the increase in supply will not occur until later. Hence what may be deflationary later on has inflationary effects in the short run.

Will the long-run benefits erase the damage that has been done in the short run? (The investment may very well involve increased capital-goods imports, which further complicates the problem by disturbing the balance of payments.)

It is not expected that universal or general answers will be found to these problems; it is doubtful that they exist. The intent, rather, is to find the answers for a variety of particular cases, to try to identify which variables are the strategic ones to control, and what parameters make significant differences in results. Perspective on these matters is urgently needed to show whether the importance of tariff policy, for instance, justifies the tremendous amount of attention devoted to it, in comparison with the effects of gestation time, which has had little study in this context. *really!*

Another sort of information sought is what symptoms can best be watched as indicators of how far to go with any policy. Although this is not generally recognized as a basic question, it may have a very significant bearing on the effectiveness of a development program.

PREPARATORY WORK ACCOMPLISHED

Before a system can be simulated and studied by analog techniques, every relationship between variables in the system must be completely described in mathematical or other equally explicit language. The kinds of programs and policies to be applied to the system must likewise be explicitly specified. Then the economic model must be translated into a comprehensive and detailed diagram

has any one ever done this??

2

guide the inputs !
7

of analog components and signal transmissions so that the simulation is known to be feasible with equipment on hand or obtainable. |

During the past year, several different models have been worked out to this stage in a process of successive approximations toward a model and an investigation program that would be comprehensive enough to yield useful results, and yet not so complex as to be impractical to manage. (The limitation is not the analog capacity, but the ability of people to oversee and keep track of the analog's operations, and to interpret the results it produces.) It is believed now that such a happy compromise has been formulated, in the model described in the next section.

Also, during this preliminary period, one of the partial models that have been formulated has been simulated and experimented with, and a more inclusive one is currently being set up in the analog. The earlier, very elementary model represents a supply function for a single sector or industry. The supply function is of the short-run variety, but is shifted by long-run effects of capital-accumulation and of wage-bargaining, both processes depending on profits as determined by demand and supply. Experiments consisted mostly of applying exogenous changes in demand and recording the resultant time-paths of price, profit, rate of starting new plant construction, and the corresponding investment expenditures.

Currently, a two-sector open economy is being simulated. It is a much-simplified version of the multi-sector model of the proposed study. It is not being exhaustively studied, but is being used principally as a pilot model to verify and demonstrate techniques,

and to provide some experience to people who will be involved in the later study. Undoubtedly, some insight into interactions between sectors will also be gained.

THE THEORETICAL MODEL

The major piece of groundwork which the past year's work has contributed to the projected study is a model of the economic system to be studied, worked out, as explained above, to the point that the simulation is known to be feasible, and chosen as the best of several alternative models on the basis of the potential significance of the results it can yield. In order to make sure that the study will illuminate some of the actual problems of underdeveloped countries, there have been frequent consultations about the model with members of the Center for International Studies staff who are concerned with the problems of particular countries, notably India.

The resulting model is described in the remainder of this section. The description is somewhat abbreviated; further details will be supplied on request.

The imaginary underdeveloped country has a rural population that is excessive for its food-producing capacity. Thus a shortage of people is never a bottleneck in production. 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, according to disposable income and the four prices, interacting with a consumers' preference function.

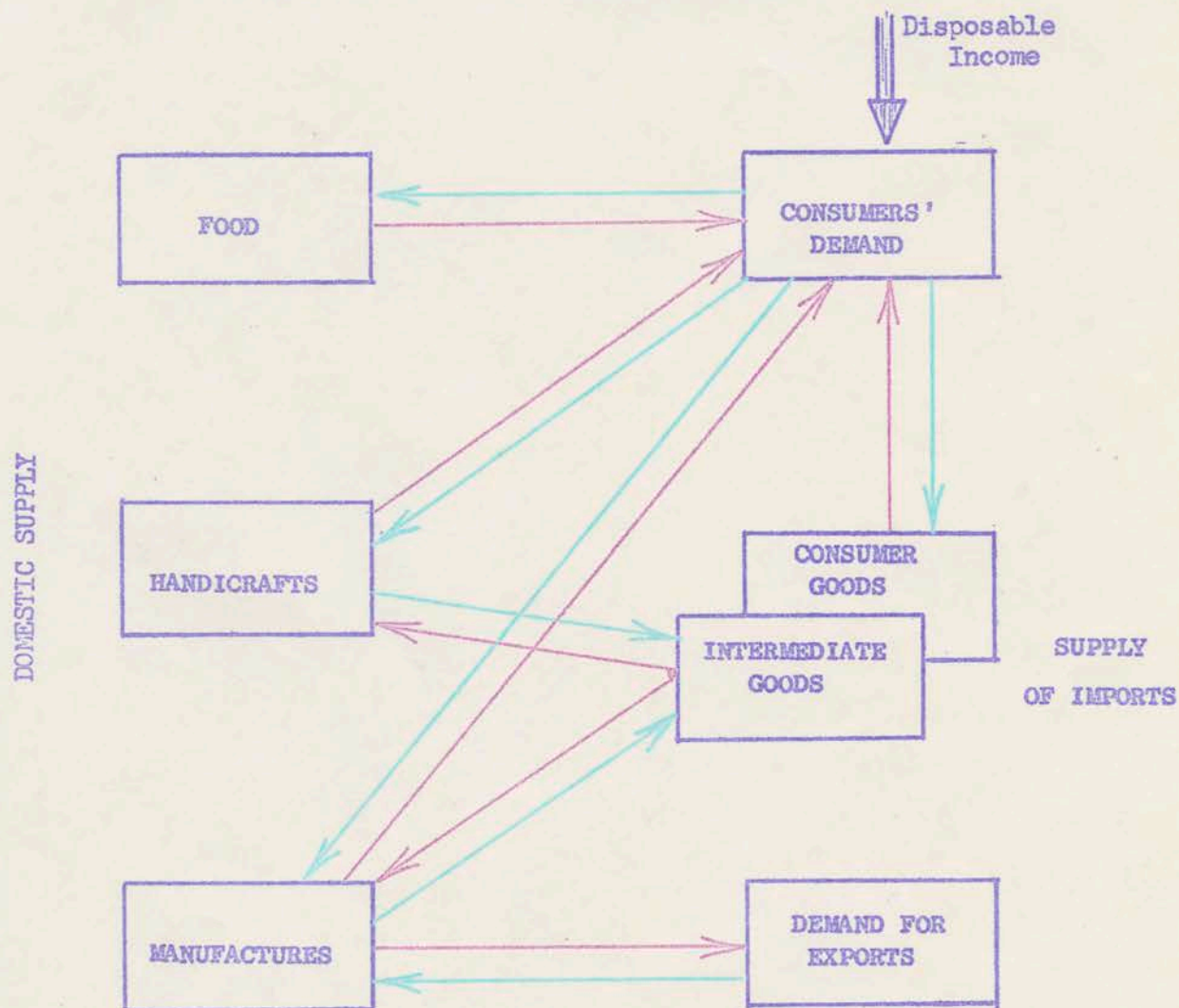
Demand for food is relatively inelastic with respect to both income and price. The other three kinds of goods are strong but not perfect substitutes for each other. They are industrially-manufactured consumer-goods, handicraft goods, and consumers' imports. The price of each kind of consumer good is determined at any time by interaction of the joint demand function with four supply functions, one for each of the four categories of consumers' goods. (See the interactions shown in Figure 1.) For imported consumer-goods, there is a fixed world price, subject to a tariff which may be changed by the government. The other supply functions are more complex, involving effects of capacity changes and (for all except food,) cost changes.



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. 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.

The handicraft sector has a low capital-output ratio and static technology, with capacity limited by the stock of critical tools.

Figure 1

SUPPLY AND DEMAND INTERACTIONS
(Consumers' and intermediate goods)

KEY:

Price 
Purchases 

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 imported-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.

Industrially manufactured consumer-goods are sold to both domestic and foreign customers. Output at any time is limited by plant capacity--but may be less than capacity if demand is low relative to the supply-price function. Initially, this sector has little or no 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 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 a domestic industry (if domestic capacity permits).

The domestic capital-goods sector has characteristics identical, except for numerical magnitudes, to the manufactured consumer-goods sector. Its capacity is initially small or zero.

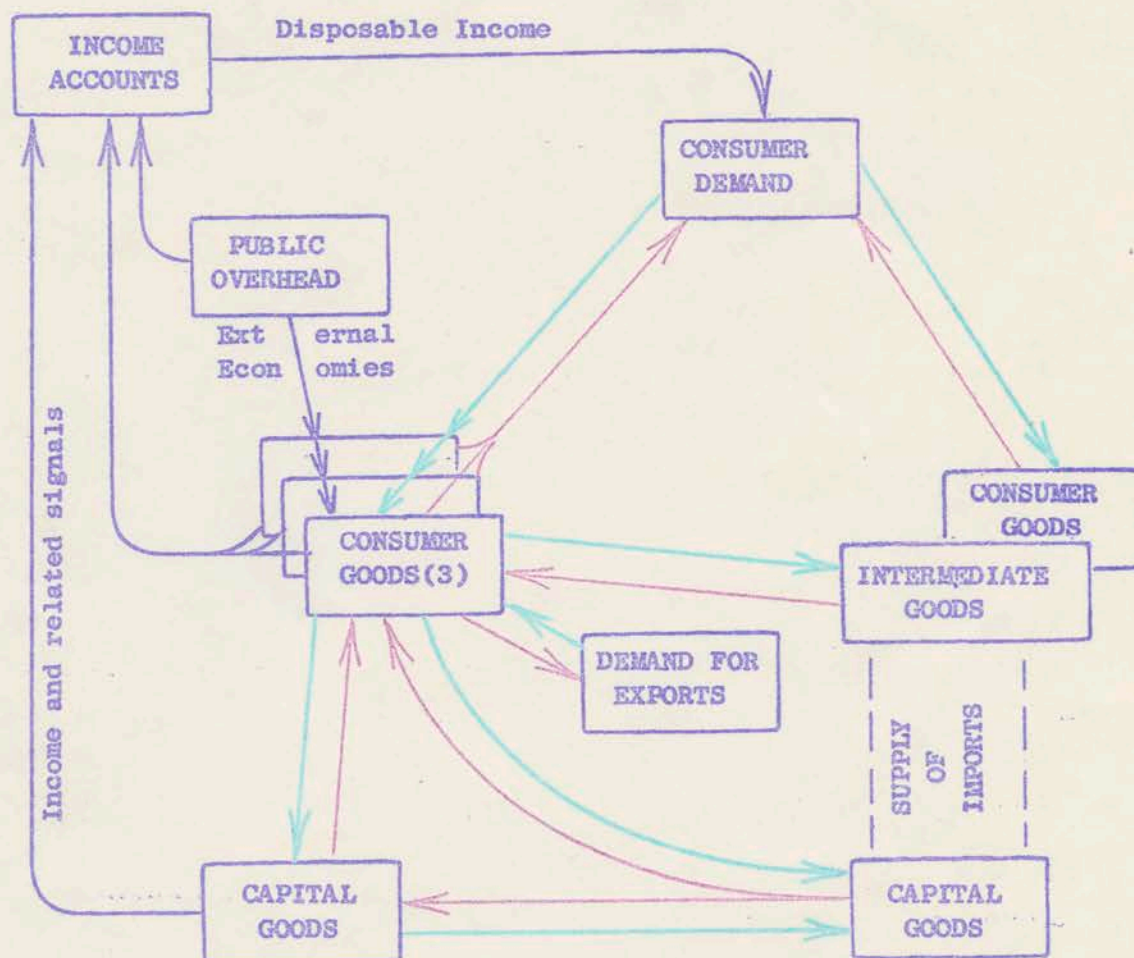
In addition to the four domestic sectors described above, there is a public overhead sector, which does not have a separately identified product, but reduces costs of production in the other sectors. Investments and current production in the various domestic sectors are reflected in the gross national 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. The principal interdependences for the whole system are indicated in Figure 2. All of the variables, through the various relationships described above, interact continuously.

Superimposed on the economic system already described, is a government program which sets 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. Using the technique described below, many alternative programs and policies will be tried out.

Figure 2

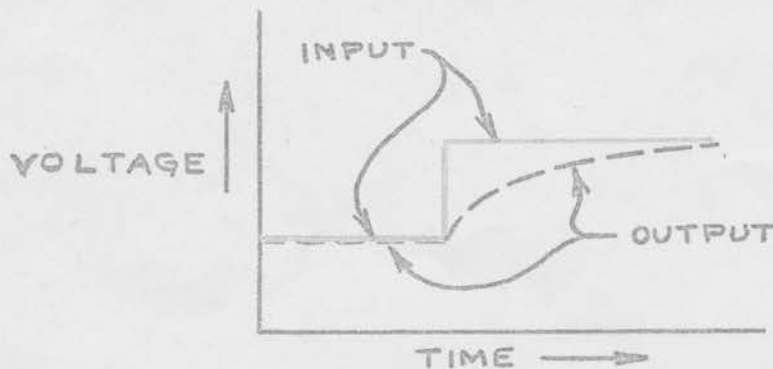
GENERAL OUTLINE OF INTERDEPENDENCES

(Not including government controls and policies)



ANALOG SIMULATION TECHNIQUE

The technique of simulation, which will be used to study this problem, is based on interconnecting various kinds of electronic and electro-mechanical units, each of which receives and produces signals which can vary continuously through time. The signal a unit produces is functionally related to the signals it receives from one or more other units. Different kinds of units embody different relationships, some depending on the past history of inputs, some on their derivatives, some just on current values. The simplest type of unit receives several varying signals and produces their sum continuously. Another type, a "lag" unit, responds to a single input about the way the speed of an automobile responds to changes in the accelerator position. An abrupt change in incoming signal causes the outgoing signal to start immediately changing toward the level of the incoming signal, but to change less rapidly as it approaches. (The function is an exponential lag.) Graphically:



Other units can select one of two incoming signals, depending on the magnitude of a third, or impose a ceiling on a signal, or multiply two magnitudes, or integrate a varying signal, (so that if the incoming signal represented a fluctuating rate of flow of liquid into a tank, the signal produced would tell the level in the tank.) These and a number of other kinds of units can be interconnected to simulate much more complex relationships.

To illustrate the principle, there follows a simple example, translating a dynamic income-multiplier relationship into a diagram of analog units and connections:

Example: Consumption, C , tends toward a constant proportion, c , of income, Y . In equilibrium, $C = cY$, but adjustment to changes in Y involves a time-lag of the kind described above. This may be expressed explicitly in terms of the rate of change of C :

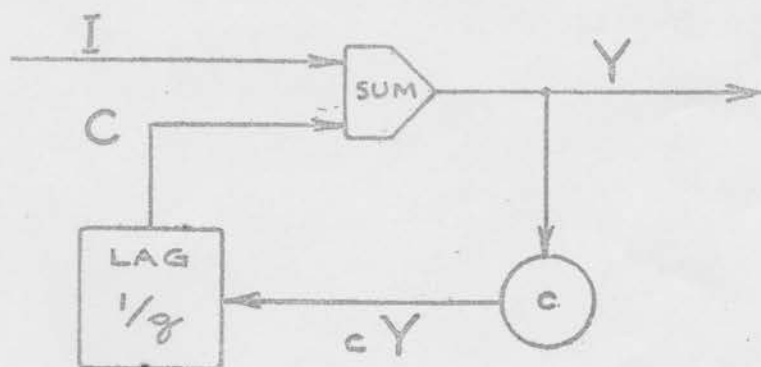
$$\frac{dC}{dt} = g \cdot (cY - C)$$

--where g is a constant.

Combining this with the accounting identity, $Y = C + I$, makes a system relating income, Y , dynamically to investment, I .

The analog of this system uses three units, one to add C and I , one to multiply Y by the coefficient c , and one to produce C as a lagging counterpart of cY . The time constant of the lag unit is chosen to give a

convenient time-scale in the analog. For instance, one second of analog time might represent one year of real time. The arrows in the diagram below show what information comes into and comes out of each relationship; in the analog they are actually wires, carrying voltage signals.



When this is set up in analog components, the voltage representing I could be varied in any arbitrary way, and the corresponding variations in Y recorded. More important, the incoming signal, I , can be produced by other analog units representing an investment decision function, which in turn responds to market prices, costs, and financial conditions. Likewise, the signal produced, Y , can be connected as one of the inputs to a demand function, and so on. Thus a large number of separate dynamic relationships can be interconnected so that they interact continuously.

Of course, the simple system diagrammed above can be completely analyzed mathematically without recourse to analogs, but when a large number of relationships are involved, some of which are

nonlinear, direct analysis becomes impossible. The system with which this study deals will require something like 200 analog units, of which 40 or 50 will be nonlinear. Time paths of about 24 variables will be graphically recorded in each run.

PROCEDURE OF STUDY

Once the simulated system is set up it will be subjected to various programs of investment allocation combined with built-in policy responses. For each combination, 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 one or more runs will often be used as a basis for shaping new programs or modifying policy mechanisms and trying again, in search of better results. One of the advantages of analog simulation over numerical calculations on digital computing machines is that results of each run are seen immediately in graphical form, and changes in program or policy can be put into the succeeding run by turning knobs. Thus it is very convenient for cut-and-try fitting of a program to desired goals. In those cases where no growth results from the conditions initially set up, it is even possible to adjust a parameter during a run to find the critical value at which stagnation is overcome.

After a survey of programs 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.

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 runs will be made in a period of a few weeks, and that the ensuing 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 take-off and in terms of insights into the effects of different patterns of investment allocation, the relevance of different policy variables, and the usefulness of various indicators as current guides to policy and program modifications.

Budget for Analog Study of the

Economic Take-Off Problem

March 1, 1958 - June 30, 1959

I. Salaries and Wages

Holland (16 months)
Research Assistants
(2 for 16 mos., 1 for
1 yr. @ \$270 per month.)
Secretary (16 months.)

\$10,700.

11,880.

4,000.

\$26,580.

*Help down details of the legend
get values for parameters
work with Indian project
and qualifying people*

II. Travel

200.

III. Publication costs

2,000. — Subvention for publication

IV. Laboratory costs
(Salaries and materials)

7,000. — 3 month extension use
grad. engineers
research assistant
supervision & maint

V. Center for International Studies
Supervision, Administration
and Supporting Services

2,900.

Total Direct Expense

\$38,680.

MIT Indirect Expense
(25% of Direct Expense)

9,670.

TOTAL

\$48,350.

4. Walkiewicz - Rockefeller Brothers Fund