

Economic Dynamics
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A MODEL FOR SIMULATING
DYNAMIC PROBLEMS OF ECONOMIC DEVELOPMENT

by

Edward P. Holland,
Benjamin Tencer, and Robert W. Gillespie

Center for International Studies
Massachusetts Institute of Technology
Cambridge, Massachusetts
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PREFACE

By E. P. Holland

The model described in this working paper is an improved and quantified version of one which I formulated in 1957-58 for simulation by means of analog computer equipment.¹ Following the original formulation in abstract terms, Messrs. Tencer and Gillespie joined me in an extensive study of Indian statistics and in consultations with India experts in the Center for International Studies, from which we arrived at estimates of parameters and at the same time decided on some significant revisions in the abstract structure of the system to make it more like the Indian economy. The analog simulation, attempted during 1958-59, failed for lack of experienced operators and of enough maintenance people to keep the rather run-down equipment working properly. After abandonment of that effort, the model was translated into a form appropriate for processing by digital computer.

The change in computer technique did not require any basic conceptual changes, but imposed some restrictions, while removing some others, on the formulation of particular dynamic interactions. As opportunities for more realistic or more complete formulation were

1. E. P. Holland, An Analog Model for Studying Economic Development Problems, M.I.T. Doctoral Thesis, 1958; and the Center for International Studies report C/58-6, 1958 (now out of print).

recognized during the translation process, they were accepted; this led also to further study of statistics and refinement of the estimates of various parameters.

Using the model thus developed, Tencer has explored the effects of alternative investment allocation patterns on the development of the economy, and Gillespie has investigated different exchange rate and tariff policies as mechanisms to adjust the balance of foreign payments. They are currently analyzing the computer outputs, and their results will probably be published in 1961.

Meanwhile it seems desirable to present the revised model in a working paper which also gives some explanation of the problems addressed, the techniques and procedures being used, and some of the underlying rationale. For this purpose, the present paper includes (in Part I) the three introductory chapters of my original model-formulation paper, revised to correspond to the changed technique and model structure. Following this, Part II is a new and up-to-date detailed description of the model, from the doctoral theses of Tencer and Gillespie.

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PART I

INTRODUCTION AND GENERAL DESCRIPTION

CHAPTER 1

PROBLEMS OF DEVELOPMENT POLICY

This report describes a dynamic macroeconomic model which was formulated for studying some of the problems of initiating economic development in a country like India. The study is being carried out by comparing numerical time histories generated by a computing machine¹ for a variety of hypothetical situations and policies.

The need for this sort of approach to the problem, and its resemblance to engineering systems analysis, are discussed and the technique is described in Chapter 2. First, however, the economic problem is described and discussed in the remainder of this chapter.

In the kind of country to which the study is relevant, (e.g., India), output per capita is initially quite low and is mainly agricultural and handicraft products and personal services. 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. The problem of concern is how to bring about what Rostow has named "the take-off," which he defines as an interval of two or three decades:

1. The IBM 704 of M.I.T.'s Computation Center.

. . . during which the rate of investment increases in such a way that real output per capita rises and this initial increase carries with it radical changes in production techniques and the disposition of income flows which perpetuate the new scale of investment and perpetuate thereby the rising trend in per capita output. . . .¹

This, of course, is not a purely economic phenomenon:

. . . The take-off requires . . . a society prepared to respond actively to new possibilities for productive enterprise; and it is likely to require political, social and institutional changes. . . .²

Some theorists maintain that initiation of economic development is purely a noneconomic problem. In this view, economic growth is like the growth of a plant. To encourage it, one tries to establish a favorable environment, but does not tamper with the process itself. Remove joint family obligations, religious prohibition of interest charges and other commercial practices, and legal obstacles to free trade between regions and groups, and somehow modify people's attitudes of disdain for money-makers, and the economy will thrive. Others have noted, however, cases where the beginnings of economic progress seem to have preceded and induced some of the appropriate changes in social structure, culture, and even religious doctrines.

No doubt the truth is that certain noneconomic conditions--as well as certain economic conditions--have to be established before the process of take-off can fully succeed, but that some of these

1. W. W. Rostow, "The Take-off into Self-sustained Growth," The Economic Journal, March 1956, p. 25.

2. Ibid.

conditions can be established during the take-off, rather than all having to be accomplished beforehand. The great importance of non-economic factors is not denied in this study. Neither is the importance of establishing economic preconditions, which may take a long time and without which the take-off may be impossible. Study of these aspects, however, is left to others. This study is directed solely to the economic dynamics of the take-off. Any notion that this aspect of the problem is clear and simple is vigorously denied.

Apart from this question, however, is the question of laissez-faire versus central planning, or rather of degree in between. Faith in the "invisible hand" is not so widespread in advanced countries as it was before the Great Depression, and there probably never was much faith in it in the underdeveloped countries. The rulers of Russia--however much we may despise their flouting of personal freedom--have demonstrated one way of bringing an underdeveloped nation up to advanced industrialism in forty years. Earlier, Japan had demonstrated another way, with less central control but with the government actively manipulating the economic incentives and deterrents. In countries where economic development is a popular objective today, it is taken for granted that government responsibility extends at least to the manipulation of foreign commerce, the tax structure, and the money system, to the over-all planning of development patterns on a sectoral level, and usually also to the actual building and operation of public transportation, power, communication,

irrigation, and other such systems. There is no real question whether the government should exercise controls to try to steer development. There are, however, plenty of questions about what kinds of manipulation will be most conducive to progress. These are the questions on which this study is focused.

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 at any time 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?

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 complicate the problem by disturbing the balance of payments.)

Two of the most difficult aspects of the problems faced by the makers and executors of development policy are, first, the conflict between immediate symptoms and ultimate effects of any action and, second, the multidimensional nature of both the goals and the effects of various actions. Whether their decisions are actually effective toward any particular goals, 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.

The need for a different theoretical technique than those that are currently conventional in economics arises from the complex nature

of the system and the problem to be dealt with. The questions posed above clearly call for a multisectoral model, with flexible prices, capacity limits, capital formation, foreign commerce, and various controls. Time-delays and time-spreads are basic to the physical processes of capital-formation and capital attrition; output in various sectors is limited by past capital formation; supply prices at capacity are determined differently than below capacity; and there is continuous interaction between production of various sectors, income, demand, prices, foreign commerce, and the balance of payments. These interactions are too significant to allow reaching valid conclusions from analyzing parts of the system separately with all else assumed constant; the nonlinearities invalidate linearized analysis; and the time-spreads and irreversibilities in the system, together with the dynamic character of the forces applied to it, make comparative statics of little use.

CHAPTER 2

SUITABILITY OF THE SYSTEMS-ENGINEERING APPROACH

Difficulties of Analysis

Adequate analysis of economic take-off problems, as indicated in Chapter 1, requires recognition of various nonlinearities and time-spread effects in a complex set of interdependent relationships. The nature of these relationships has frequently been described and is fairly well agreed upon. Differences of opinion center mainly on the question of which ones can be safely ignored or grossly simplified because the dynamic behavior of the whole system cannot be dealt with by verbal reasoning or direct mathematical solution. Of course, every method of study involves ignoring or simplifying some relationships, but in this problem heretofore it has had to be done too drastically.

From a postulated set of relationships to general conclusions about the system's modes of behavior is basically a matter of deduction: given a set of assumptions, to what conclusions do they lead? Verbal logic, however, proves inadequate for two reasons. First, most of the relations are not syllogisms stating that something does or does not happen depending on whether a certain combination of conditions is or is not met. Most are magnitude relations, in which

the magnitude of one variable depends on the magnitude of several others, and some involve effects distributed through time.

A second reason that verbal logic is inadequate is that the system involves many feedback loops. These are sets of relations in circular chains such that the dependent variable of a relation enters other relations which in turn affect the independent variables of the first. Some feedback loops and mutually determined variables can be dealt with verbally, but not such a complex network as this problem involves, especially when the loops also include time-lags, delays, and nonlinearities. Verbal analysis can best handle those chains of cause and effect that proceed mainly in one direction, where a few premises lead to proof of a first proposition, which is then combined with another premise to prove a second proposition, and so on, with each step finished before the next is taken and no effects coming back "upstream." As Susanne Langer puts it:

. . . all language has a form which requires us to string out our ideas even though their objects rest one within the other; as pieces of clothing that are actually worn one over the other have to be strung side by side on the clothesline. This property of verbal symbolism is known as discursiveness; by reason of it, only thoughts which can be arranged in this peculiar order can be spoken at all. . . .¹

Various mathematical techniques also have shortcomings for the problem at hand. This is partly because of limitations of the

1. Susanne K. Langer, Philosophy in A New Key, Cambridge, Harvard University Press, 1942, Mentor Edition, pp. 65-66.

mathematics and partly because the relative merits of different results cannot be evaluated by a single criterion. Linear (or even nonlinear) programming is an excellent technique for maximizing or minimizing a single criterion under conditions of general equilibrium. The quantities in the general equilibrium may be expanding through time, but the situation is essentially what Baumol describes as "statics involving time"¹ rather than dynamics. The circuit is not closed through incomes, consumer preferences, and market prices, with positive profits affecting investment and with inflation limiting the rate of investment that is tolerable.

Models which are more dynamic have been offered under the general headings of Business Cycle Theory, or Fluctuations and Growth. Most of the dynamic mechanisms that are significant in business cycles are also significant in the take-off process, and a really adequate dynamic model should be suitable for studying both phenomena. An interesting collection and comparison of models of this type is presented by R. G. D. Allen.² Models included are those of Samuelson, Hicks, Goodwin, Kalecki, and Phillips. A more sophisticated and elaborate one has more recently been formulated by Smithies.³ All of these deal with income and product interchangeably, i.e., with

1. W. J. Baumol, Economic Dynamics, New York, Macmillan & Co., 1951, pp. 1-3.

2. R. G. D. Allen, Mathematical Economics, London, Macmillan & Co., 1956, Chapters 7 and 8 and pp. 285-289.

3. For the primary references on all six models, see "Dynamic Economic Models" in Bibliography.

fixed prices, or deal solely with income, disregarding physical quantities and prices. None are open to foreign commerce, or distinguish between different kinds of goods, or have output limited by capacity (although Kalecki and Smithies at least go so far as to make investment sensitive to some relation between output and capacity). These criticisms are no reflection on the authors; they reflect, rather, on the limitations imposed by mathematical methods which are chosen to allow solution for general rather than particular cases. The article by Smithies in particular offers a number of examples of the disparity between the elements the author considers relevant and those to which he is limited by the mathematics. For example, after explaining and justifying the assumption that profits have a dominant influence on investment, he finds it necessary to assume that profits are a fixed proportion of gross national product. Given a technique that permitted it, Dr. Smithies surely would have preferred to allow for some of the factors that make profits high at some times and negative at others.

The Control-System Approach

In the search for more effective ways to deal with dynamic economic systems, several people have noted the strong similarity between such systems and feedback control systems in engineering. The spectacular development of control-system engineering since the beginning of World War II certainly should have produced some tools that could be adapted to similar systems outside of engineering. One

of the keys to this tremendous development was the use of the Laplace transform to study systems in terms of their "frequency response spectrum" from which their dynamic behavior under any conditions could be deduced. In Tustin's book,¹ which is a great pioneering effort to make the techniques of his field (electrical engineering) available to economists, this technique is the most prominent. Allen also presents it in his chapter on closed-loop systems.² Unfortunately, as they both point out, there are serious doubts about the usefulness of this analysis to economics, because it applies only to linear systems. The engineer often takes pains to design his system to be linear, just so that he can analyze it better, but this choice is not open to the economist. He knows that the economy has important nonlinearities, and he cannot change them.

Other parts of Tustin's and Allen's expositions, however, offer some tools that are more certain to be helpful. Just the symbolism of drawing feedback relationships in block-diagram form is a great help for tracing information from one relation to another and for seeing which variables are independent relative to the system as a whole or any part of it. For the discursive form of language and algebra, it substitutes a pattern of relations that can be seen like a map. Simply translating an economic model into this form can give

1. Arnold Tustin, The Mechanism of Economic Systems, Cambridge, Harvard University Press, 1953.

2. R. G. D. Allen, Op. cit., Chapter 9.

new insight into its character, as shown by Allen's diagrammatic comparison of the several models mentioned before.¹

There still remains the problem of analyzing a complex dynamic nonlinear system. All attempts to get direct mathematical solutions seem to fail. How to break through this mathematical barrier is suggested by Allen in discussing the advantages of some other engineering approaches to control-system problems:

. . . the engineer does not often attempt general solutions; he aims at computing (by numerical or graphical methods) particular solutions, usually a whole string of them. . . . As economic models become more complex, and have a greater empirical content, to make them applicable to the real world, the answers to general questions become less possible. The economist may need, therefore, to shift his ground from the general to the particular, and to follow the methods and the experience of the engineer.²

This means forgetting about formulating the problem so that a solution is possible in mathematical symbols, and instead widening the limits of formulation to include whatever can be solved numerically, graphically, or by any other means, for particular cases. This approach usually requires a large number of solutions to survey the effects of changing various parameters and of applying different disturbances, but if that can somehow be done, it can be very enlightening.

This approach has been used with rewarding results by Phillips, in his two well-known studies of stabilization policy.³ In each of

1. Ibid., p. 285.

2. Ibid., p. 304.

3. A. W. Phillips, "Stabilization Policy in a Closed Economy," The Economic Journal, June 1954, and "Stabilization Policy and the Time-Form of Lagged Responses," The Economic Journal, June 1957.

these he has postulated a simple income-flow model with particular parameters, has subjected it to arbitrary disturbances, and has tried out various formulations of stabilization policy, to see which have desirable dynamic effects. Conclusions are based on comparisons of many particular cases. Incidentally, the results of the second study strongly bear out a point that both Tustin and Allen emphasized: that the form of time lags is very important to the stability of a feedback system--assuming a discrete delay when the actual process involves a distributed lag, or vice versa, may lead to significantly false conclusions.

Application of this approach to a system complex enough for studying the take-off problem requires comparison of a very large number of time-histories, computed for different hypothetical cases. Calculation "by hand" would be entirely too cumbersome to consider. Two alternatives are available: digital and analog simulation. Either of these methods can do the job, given adequate equipment and staff. Each has advantages and disadvantages, but the choice between them is most likely to be based on the equipment that is accessible. Only a few analog laboratories have sufficient capacity and versatility for a model as complex as the one described here. A suitable digital computer is one comparable to the large-capacity version of the IBM 704 (32,768-word storage), used with an appropriate generating program.

Past and Current Simulation Studies

Analog and digital simulation techniques differ, as explained in later parts of this chapter, but serve similar purposes. Thus the word simulation has come to apply to both.

To date the most fruitful use of analog simulation of an economic system has probably been the 1957 study by Phillips discussed above. It definitely contributed new insight into the dynamics of stabilization policy, revealing significant effects of nonlinearities that formal mathematical analysis had not dealt with. Earlier studies simulated a simple inventory-fluctuation model,¹ the Goodwin business-cycle model,² and the Kalecki model.³ Unlike Phillips' study, these were primarily experiments in applying the technique to problems for which solutions had already been found by other means (except the effect of parameter variations in the Goodwin model). They were interesting demonstrations of the technique, but did not create awareness of its potential utility for problems that are otherwise intractable. Still earlier analogs--hydraulic rather than electrical--

1. N. F. Morehouse, R. H. Strotz, and S. J. Horwitz, "An Electro-Analog Method for Investigating Problems in Economic Dynamics: Inventory Oscillations," Econometrica, October 1950, also R. H. Strotz, J. F. Calvert, and N. F. Morehouse, "Analog Computing Techniques Applied to Economics," Transactions of American Institute of Electrical Engineers, Vol. 70, Part I, 1951.

2. R. H. Strotz, J. C. McAnulty, and J. B. Naines, "Goodwin's Non-Linear Theory of the Business Cycle: An Electro-Analog Solution," Econometrica, July 1953. Reprinted as Cowles Commission Paper, N.S. 74.

3. O. J. Smith and H. F. Erdley, "An Electronic Analogue for an Economic System," Electrical Engineering, April 1952.

were invented by Phillips¹ and by Abba Lerner.² These were useful for illustrating the interdependences in the systems they represented, but not for investigation beyond the limits of algebraic solution.

Digital-computer simulation has so far been applied more to problems of the firm and industry than to macroeconomics. A discussion of such applications, with illustrative examples, has been presented by Forrester.³ A discussion of methodology and references to some current studies were presented at the 1959 Annual Meeting of the American Economics Association by Cohen,⁴ who has also used this technique to study the interactions between shoe, leather, and hide producers.⁵ One macroeconomic simulation was described at the December 1958 meeting of the Econometric Society.⁶ A very extensive bibliography of simulation studies--mostly digital, but a few analog as well--has been assembled by Malcolm.⁷

1. A. W. Phillips, "Mechanical Models in Economic Dynamics," Economica, 1950.

2. Abba Lerner's model, of about 1951, is known to this author only by hearsay. It was evidently similar to Phillips'.

3. Jay W. Forrester, "Industrial Dynamics--A Major Breakthrough for Decision Makers," Harvard Business Review, Vol. 36, July-August 1958. A book on the same subject by the same author is due to be published in 1960 or 1961 by the Technology Press of M.I.T.

4. Kalman J. Cohen, "Simulation of the Firm," American Economic Review, May 1960 (Papers and Proceedings of A.E.A. annual meeting.)

5. Kalman J. Cohen, Computer Models of the Shoe, Leather, Hide Sequence, Englewood Cliffs, N.J., Prentice-Hall, 1960.

6. James S. Dusenberry, Otto Eckstein, and Gary Fromm, "A Simulation of the United States Economy in Recession," presented to the Econometric Society, Chicago, December 28, 1958.

7. D. G. Malcolm, "Bibliography on the Use of Simulation in Management Analysis," Operations Research, March-April 1960.

Analog Simulation

The basic idea of a simulator (or analog) is explained by Tustin as follows:

A simulator is a physical system, analogous to the model to be studied, in which there is a more or less complete part-by-part correspondence, the variables that are significant in the model appearing as analogous variables--mechanical, electrical or hydraulic or other quantities--between which corresponding relationships are set up by suitable construction.¹

A general purpose electronic analog has an assortment of units, each representing some elementary functional relationship such as summation, integration, multiplication by a constant, or exponential time lag. Through wires from other units, each unit receives voltage signals proportional to the variables which are independent in the relationship it represents, and produces a voltage signal proportional to the dependent variable. The input voltages may vary in any manner with time, and the output voltage will vary correspondingly. This output signal may be wired in as an input to one or more other units and may also be recorded graphically or displayed on an oscilloscope tube. With an appropriate selection of units, suitably interconnected, it is possible to simulate the dynamic behavior of a very complex system involving feedback loops and time lags. Parameters of each relation in the system may be altered by turning knobs, and the effects on the behavior of the system may be surveyed by making series of runs with systematic alterations of the parameters.

1. Tustin, Op. cit., p. 127.

The equipment used in our attempted simulation was of this general-purpose type, mainly electronic, but also including some electro-mechanical components for purposes less easily accomplished electronically.¹ It was originally designed for simulation of airplane and missile flight dynamics and associated control and guidance systems. Many kinds of nonlinearity were provided for--e.g.: limiting, selection, multiplication of variables, square roots, time delays of different forms, and arbitrarily-shaped functions of two variables.

From this stock of equipment, appropriate units were set up and interconnected to correspond to our model, as well as to the programs and disturbances to which it was to be subjected. For each run, model parameters of the disturbances, programs, and policies would be set to the desired values. Then the system would be activated and would act out a run. Voltage signals previously selected wherever desired in the system would be recorded on time-graphs by moving pens. The run would be switched off either when it was considered to have covered enough time or when some variable had exceeded its allowed range. Voltages recorded represented time histories of such information as output and prices in various sectors, wages, national income, imports, and exports. From these graphical results, immediately available, it was possible to decide on parameter or program alterations,

1. The equipment was that of M.I.T.'s Dynamic Analysis and Control Laboratory, an organization which was in the process of going out of business while we were trying to use its facilities.

make them by turning corresponding knobs, and make another run. Each run itself would take less than a minute. Thus the procedure was extremely flexible and convenient for feeling out unexplored areas and for fitting a program by cut-and-try methods to a set of goals. These were primary reasons for trying to apply this technique to the economic take-off study.

Although no worthwhile runs were recorded with the completely elaborated model set up in terms of this equipment, a simpler model, with two domestic sectors, foreign trade and consumers' demand, was simulated earlier and produced enough runs to demonstrate the technique.¹ This model, although much simpler than the one attempted later or the one described in this paper, went considerably beyond the limits of models that can be directly analyzed by mathematical methods. It was also (so far as we are aware) the most advanced economic-system model to have been simulated up to that time. It was not used for a systematic study, however, because of the false expectation that the more complex model would soon be in operation.

The fact that this analog simulation of an underdeveloped-economy model failed and was superseded by a digital-computation study is, of course, interpreted by some digital-computer partisans as clear proof of superiority of their favorite equipment. Such an

1. Results of a sample run are shown with a description of the technique and the "simple" model, in CIS paper C/58-17, Analog Simulation of an Economy Beginning to Develop, which was presented at the Econometric Society meeting in Cambridge, August 1958.

interpretation is untenable in view of the semiabandoned state of the analog equipment, the lack of experienced operators, and the inadequacy of the maintenance staff, in contrast to the new and well-staffed digital computer facility. The trend does indeed seem to be toward digital computation, but the present case is not a valid comparison of the alternatives.

"Simulation" by Digital Computer

A digital computer cannot act as a simulator in the literal sense of the word as used by Tustin¹ and applied to analogs generally. By an entirely different process, however, it can generate time-paths of the variables in a system and can be used for almost the same sort of trial-and-observation study as an analog simulator. Thus the word simulation has come to denote the generation of time-paths for such studies regardless of the type of machine and its internal processes.

The process by which the digital computer does this job is extremely complex, for two reasons: (1) It can do only simple numerical operations--the four arithmetic operations plus comparison, storage of numbers, and reference to stored numbers. (2) It can do only one such operation at a time. 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

1. See quotation above, p. 17.

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; we are using 1/20th of a year) 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

$$w(t=jk) = b\left(\frac{x}{y}\right)(t=j) + a$$

Where w , x , and y are variables, a and b are constants, j and k indicate successive points in time, and jk indicates the time interval between j and k . Assume that $x(j)$ and $y(j)$ 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 :

<u>Meaning</u>	<u>Code</u>
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 directly into a running program would be formidable for such a complex model as we are dealing with, and virtually impossible to check. (A recent running program for this model, generated as described below, included 3,750 operations.) Fortunately, however, we are able to make use of a "generating program" which has evolved out of several years of development work by the Industrial Dynamics group at M.I.T.¹ 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

1. The basic working paper on coding for the DYNAMO program is Memo D-47 of the Industrial Dynamics Group, School of Industrial Management, M.I.T., July 24, 1959.

See also note 3, page 16 above.

general instructions that are given by the investigator. The relation used for the example above is specified in a special kind of algebraic form:

$$W.JK = (B)(Z.J) + (A)(1.0)$$

$$Z.J = (X.J)/(Y.J)$$

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.¹

The running program of 3,750 instructions referred to above was generated from a set of 426 equations in DYNAMO form. This is still a large number of equations, and careful checking is required, even though a good deal of checking of formal details is done by machine in the DYNAMO program. Checking the functional relationships is made easier by the fact that the equations are in a form that is directly understandable and that can be directly translated into block diagrams. Once the model has been correctly coded on punched cards, the reliability of the operation is much greater than with the

1. The job could presumably be done with the older and better-known FORTRAN program, but DYNAMO is more convenient and foolproof for the user who is not a programming expert.

analog. The relationships on the cards remain as coded, and are not subject to the malfunctioning of electronic circuits. The digital computer itself, of course, has occasional electronic breakdowns, but these are usually such that the operation is either correct or obviously wrong, rather than subject to errors that grow gradually.

An important convenience of the digital computer is that it does not require a lengthy setup operation for each different study, and thus can spend a few minutes on one researcher's problem, then a few minutes on another, and so on. Thus, instead of trying to carry out a whole study in one or two continuous sessions, the investigators can do it in smaller parts, taking as much time as necessary to analyze some of the results before proceeding.

CHAPTER 3

GENERAL DESCRIPTION OF THE SYSTEM

This chapter begins the description of the model which was simulated on the IBM 704. It discusses concepts and describes the model in outline to give the picture of the over-all system and the relations between its various major parts. Chapters 4 through 9 fill in the details, defining each relation specifically, in words, equations, and diagrams.

Evolution of the Model

The model was originally formulated as a purely hypothetical one, and in symbolic terms, without numerical values.¹ 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 as much as possible on a particular country. This

1. In CIS report C/58-6, An Analog Model for Studying Economic Development Problems, by E. P. Holland (out of print; on file in M.I.T. library as Ph.D. thesis in Economics.)

did not mean that the model would be restricted to the parameters estimated for that country. However, 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 was 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 parameters relating to dynamic response and to time lags. Some of these values had to be adjusted by trial and observations until the response characteristics of the parts of the system including them seemed plausible. Results have been tested for sensitivity to errors in the estimation of some selected 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 certain problems as they are manifested 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 were unrealistic, at least for India. When the failure of the analog simulation led to recoding the model in digital-computer language, the entire formulation was reviewed and revised to match the model more closely to the pattern of the Indian economy. For example, a number of intersectoral product demands were added, and the form of the consumers' demand function was changed to give a more plausible effect of income on the demand for food. The change in technique did not require any change in basic concepts or in the fundamental formulation of relations. The handling of what had formerly been mutually-determined variables became more cumbersome in the digital formulation, but in some other relations improvements in form became possible. The total complexity of the system became less limiting, and some advantage was gained from this relaxation. The present model, however, is not basically different but is a refinement of the old one.

Concepts

To be useful, of course, the model must have some reasonable relation to the thousands of different activities that compose the economies of real countries. Obviously it cannot represent them all in detail, but must omit much of what is real, including only what seems most important. Hundreds of different kinds of activity

must be lumped together in each of the various aggregate quantities that are the variables of the model. How the grouping is done depends on the purposes of the model and on some notion of the characteristics of particular countries which the model is intended to resemble.

The theoretical aspects of grouping production activities into aggregates are explained by Mathilda Holzman in her chapter of the Leontief group's study.¹ It is justifiable to combine goods which are close substitutes and have similar production functions, and to combine goods without regard to production function if they are complements. Also, although Miss Holzman does not have occasion to discuss it, sequential activities may be combined, as if the sector were composed of vertically integrated firms.

These considerations apply conceptually to this model, although on a rather loose basis, since the sectors are few and very broad. Each production sector is conceived of as producing a large variety of goods which could be grouped into sets of complementary goods on the basis of stability of the ratio in which they are purchased. Each such set, as a set, has about the same production function and the sets are fairly close substitutes. Substitution also obtains within the sets. Vertical integration is assumed complete in each sector,

1. W. W. Leontief and others, Studies in the Structure of the American Economy, New York, Oxford University Press, 1953; Chapter 9: "Problems of Classification and Aggregation" by Mathilda Holzman.

except to the extent that some intermediate goods are imported or transferred from one sector to another.

Distinctions between the sectors are on the basis of different production functions or different uses of the product. Thus nonpower- and power-manufactured consumer goods are substitutes, but differ in capital-output and labor-output ratios, while power-manufactured consumer goods and capital goods have similar production functions, but one is used mainly by consumers, the other only by manufacturers, and productive capacity is not convertible from one of these uses to the other. Imports are distinguished by their use as either consumer goods, intermediate goods, or capital goods. Goods for export are treated as a composite of the products from the agriculture and consumer-goods sectors on the basis that they compete with those products for factors of production. (E.g., the largest component of India's exports, jute, uses land which could otherwise grow rice, and factories which are similar in physical capital makeup to those producing consumer goods.)

Consumer tastes are assumed to be such that a single aggregate preference function is valid for the whole population. No income-distribution effects are assumed except that profit-earners tend to save more. Their extra savings are accounted for as if they were retained in businesses; their consumption preferences otherwise are like all others. Consumption and production are assumed equal; there

are no unintended or speculative inventory changes, and the inventory growth connected with capacity expansion is included in capital formation.

The degree of integration in each sector is presumed to go from the production inputs through to delivery and servicing of finished products. "Production inputs" include natural resources that are specific to the sector in question and intermediate goods and services (including, for example, transportation of end products) procured from other sectors. This inclusiveness, of course, goes beyond the rigorous limits of Miss Holzman's prescriptions and leads to serious questions about product mix and index number validity. These will not be discussed further here, however. Either these gross and questionable aggregates must be used, or macroeconomics must be abandoned.

The output of each sector is treated in the model as a flow of a homogeneous quantity. Its flow rate may change on very short notice, almost varying continuously. Likewise, payments and information signals are almost continuously variable. The actual digital-computer program performs a recursive period-by-period computation, but very short periods (1/20th of a year) are used. This permits approximately continuous interaction among variables and frees decisions from the rigidity of once-a-year or once-a-quarter review for whole aggregates, which certainly would yield some special and unrealistic results. Of course, where delays or periodic decisions are appropriate for particular relationships, they are explicitly introduced.

Payments are conceived of as flows of signals which have effects like ordinary transfers of cash, but include also some accruals and imputations. For example, a credit sale is construed to include a payment because it has the same effect as a cash sale on the manufacturer's production decisions. The essential feature of payments, under this concept, is their effect on decisions--decisions to produce, to invest, and to consume. Thus the money associated with a payment may be imaginary or may be newly created in the process of payment. However, the quantity of money in the system is not an explicit variable in this analysis and does not have to be accounted for.

Over-all Structure of the Model

The model represents an underdeveloped country (based on India) whose rural population is more than can be utilized on its food-producing land. Population grows exponentially at a rate determined exogenously. 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.

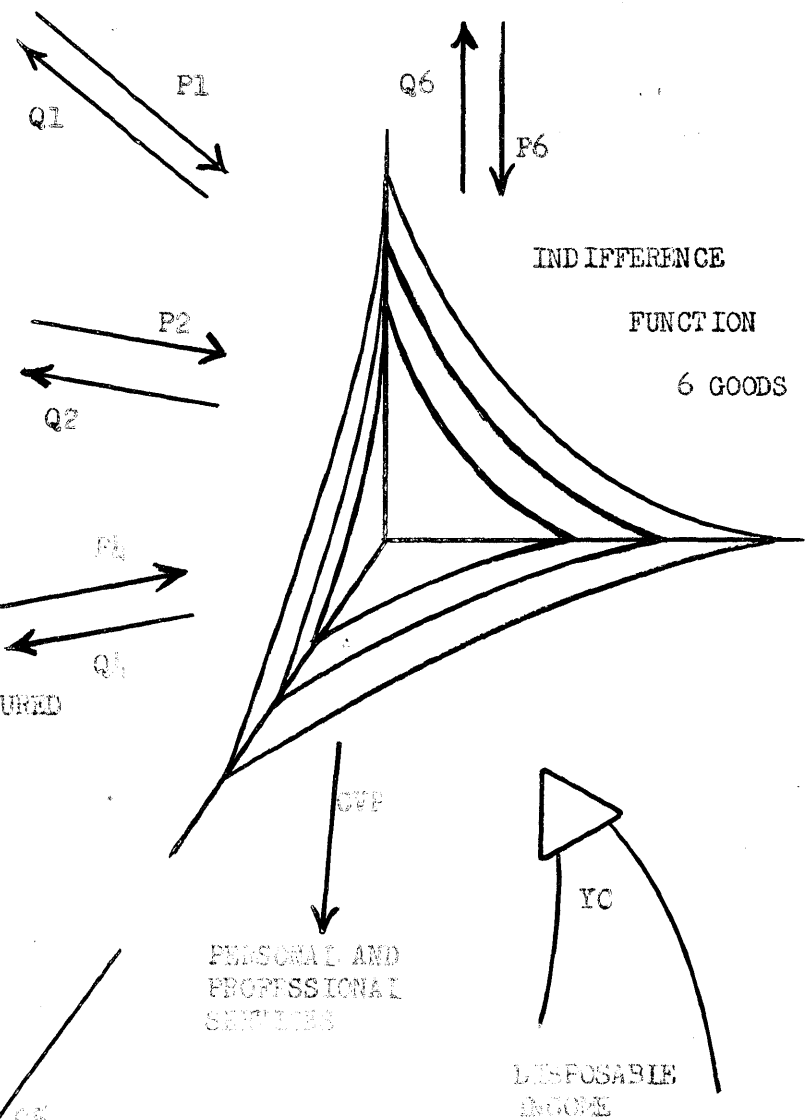
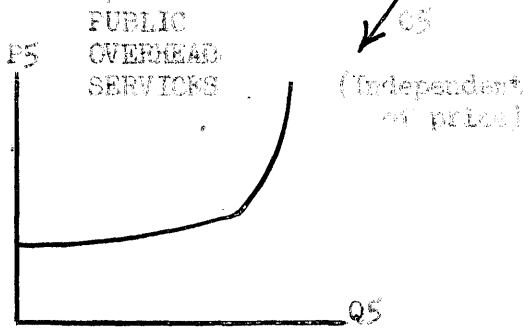
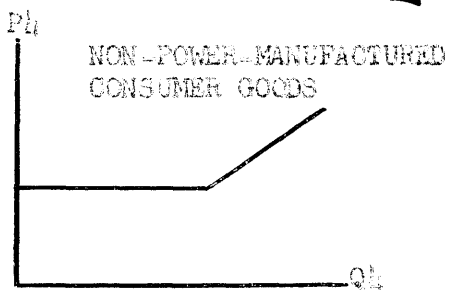
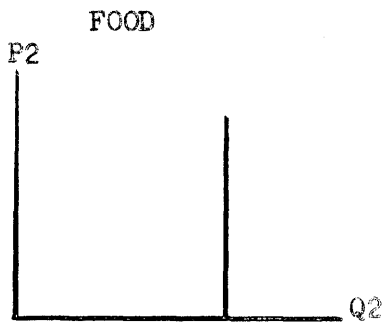
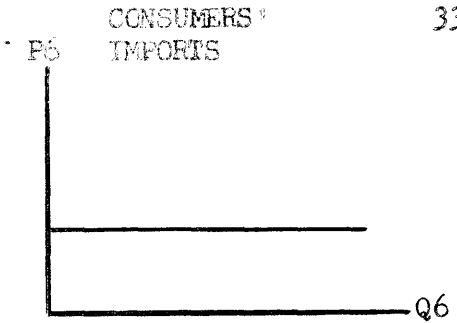
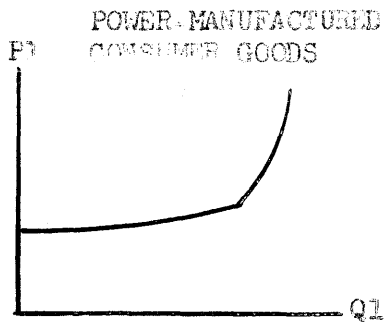
Consumers' expenditure flows at any time are distributed among four categories of goods and two categories of services. A joint demand function, responding to population, disposable income, and the various prices, determines the level and pattern of consumers' demand which in turn reacts with supply functions for the various

goods to determine their respective prices. These interactions are indicated schematically in Figure 1.

Consumers' demand for food is relatively inelastic with respect to price. Its income-elasticity, close to one at low income levels,¹ declines as per capita income increases, in consonance with Engels' Law. Savings and the demands for all other goods and services have income-elasticities greater than one and increasing as that for food declines. Demand for each of two kinds of services (public overhead and personal) is unit-elastic with respect to price. The other three kinds of consumer goods are substitutes for each other (but not perfect substitutes). They are consumer goods from power-using factories, from nonpowered shops, and from foreign sources. (Food imports are not included in the latter. They are added directly to the domestic supply, and not differentiated in the demand function.)

The total demand for any product (except exports and government services) comprises the demand by domestic consumers and demands from other sectors in which the product is used as an intermediate good or as an ingredient of capital facilities. In addition to the sectors which produce primarily for consumers, there is one in which capital

1. Exceptions to this statement, and to various others describing the "normal" characteristics of the model, occurred in occasional runs where parameters were altered for exploratory purposes. Such deviations may not always be mentioned in the model description but will, of course, be explained when results of those runs are presented.



PERSONAL AND PROFESSIONAL SERVICES

DISPOSABLE INCOME

FIGURE 1

CONSUMERS' GOODS.
SUPPLY AND DEMAND

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

Figure 1 shows only the interactions involving consumers; the complete set of demand relations--final and intermediate, including both current output and capital formation--is shown in the form of an input-output table as Figure 2. Figure 3, at the end of this chapter, is a diagram of these relations, suggesting also the feedback effects of prices, the relevance of income and population to consumers' demand, and the possibilities of controlling investment and foreign trade for stabilization and development.

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 help determine personal savings and the expenditure on each kind of consumer good, as described initially.

FIGURE 2
INPUT - OUTPUT TABLE (SYMBOLIC)

	current output						capital formation					final demand					
	1	2	3	4	5	8	CVP & GOV	K1	K2	K3	K4	K5	sub-total	Exports	Investment	Consumption & Gov	$P_j Q_j$
1						$P_1 Q_{18} Q_8$							$P_1 Q_{18} Q_8$			C1	$P_1 Q_1$
2	$P_2 Q_{21} Q_1$			$P_2 Q_{24} Q_4$		$P_2 Q_{28} Q_8$							$P_2 \sum Q_{2j} Q_j$			C2	$P_2 Q_2$
3	$P_3 Q_{31} Q_1$	$P_3 Q_{32} Q_{H2}$		$P_3 Q_{34} Q_4$	$P_3 Q_{35} Q_5$			$P_3 k_{31} \frac{KG1}{G1}$		$P_3 k_{33} \frac{KG3}{G3}$	$P_3 k_{34} \frac{KG4}{G4}$	$P_3 k_{35} \frac{KG5}{G5}$	$P_3 Q_3$				$P_3 Q_3$
4									$P_4 k_{42} \frac{KG2}{G2}$		$P_4 k_{44} \frac{KG4}{G4}$		$P_4 \sum k_{4j} \frac{KGj}{Gj}$			C4	$P_4 Q_4$
5	$P_5 Q_{51} Q_1$		$P_5 Q_{53} Q_{H3}$	$P_5 Q_{54} Q_4$									$P_5 \sum Q_{5j} Q_j$			CV5	$P_5 Q_5$
8														EXD 8			EXD 8
CVP, GOV																CVP + GOV	CVP + GOV
K1															INV1		INV 1
K2															INV2		INV 2
K3															INV3		INV 3
K4															INV4		INV 4
K5															INV5		INV 5
	$\sum P_i Q_{i1} Q_1$	$P_3 Q_{32} Q_{H2}$	$P_5 Q_{53} Q_{H3}$	$\sum P_i Q_{i4} Q_4$	$P_3 Q_{35} Q_5$	$\sum P_i Q_{i8} Q_8$		$P_3 k_{31} \frac{KG1}{G1}$	$P_4 k_{42} \frac{KG2}{G2}$	$P_3 k_{33} \frac{KG3}{G3}$	$\sum P_i k_{i4} \frac{KG4}{G4}$	$P_3 k_{35} \frac{KG5}{G5}$					
		$P_2 Q_{IM2}$	$P_7 Q_7$										CIM			C6	M
	bal.	bal.	bal.	bal.	bal.	0	CVP + GOV	$w_1 k_{L1} \frac{KG1}{G1}$	$P_2 k_{L2} \frac{KG2}{G2}$	$w_3 k_{L3} \frac{KG3}{G3}$	$P_2 k_{L4} \frac{KG4}{G4}$	$w_3 k_{L5} \frac{KG5}{G5}$	$\sum V.A. = GNP$	X	I	C + G	
	$w_1 L_1 Q_1$		$w_3 L_3 Q_{H3}$	$P_2 Q_{L4} Q_4$	$w_3 L_5 Q_5$									GNP = X + I + C + G - M			
	bal.		bal.	bal.	bal.												
	$P_1 Q_1$	$P_2 Q_2$	$P_3 Q_3$	$P_4 Q_4$	$P_5 Q_5$	$P_8 Q_8$	CVP + GOV	$P_{k1} \frac{KG1}{G1}$	$P_{k2} \frac{KG2}{G2}$	$P_{k3} \frac{KG3}{G3}$	$P_{k4} \frac{KG4}{G4}$	$P_{k5} \frac{KG5}{G5}$					

KEY TO SYMBOLS

Following each symbol below, the equivalent DYNAMO code symbol is given before the definition. Different symbols were used in the table to save space.

- bal. a balancing item; residual
- P_i ; P_i price of sector i output
- P_{ki} ; PK_i cost per unit of i-capacity
- Q_i ; Q_i quantity of sector i output
- Q_{ij} ; Q_{ij} i-input per unit of j-output
- Q_{H3} ; $QH3$ home-produced part of Q_3
- Q_{IM2} ; Q_{IM2} imported part of Q_2 (food)
- Q_{L4} ; $QL4$ sector 4 labor coefficient in equivalent food units
- G_i ; G_i gestation time
- KG_i ; KG_i capital in gestation
- k_{ij} ; $(NCOR_j)(K_{ij})$ i required to build one unit of j-capacity
- k_{Lj} ; $(NCOR_j)(KL_j)$ labor used to build one unit of j-capacity
- L_i ; $LPQA_i$ labor per unit of i-output
- w_i ; W_i wage rate for sector i
- CIM ; CIM imported food, capital, and intermediate goods (not C6)
- $C_i, CV_i, GOV, EXD8, INV_i$ (same symbols in DYNAMO) final demands in value flow units

Foreign trade is not automatically balanced. Policies regulating tariffs or adjusting the exchange rate may be geared to the balance of payments.

Supply Functions

The supply price for consumer goods from the power-using sector depends on the costs of labor and intermediate goods and on the relation of demand to capacity. 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 off to match output. The wage rate index is negotiated upward when business is profitable, but does not go down (except in a few exploratory runs.) 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.

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. The services of this sector are used by most other producers as well as by consumers.

Output of the agriculture sector 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 which are 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 with a lag. 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.

In terms of categories appropriate to India, the nonpower-using consumer goods sector includes both handicrafts and those small-scale manufacturing concerns that use little or no powered machinery. In more general terms, this may be called the low-capital-output-ratio

sector. Technology is static, and labor productivity not only is lower than in the more capital-intensive industries but does not tend to increase. Since much of the labor force is unorganized and has farm life as an alternate opportunity, wages are closely correlated with agricultural prices. Wages and the prices of intermediate goods determine a minimum supply price for this sector's product. Hence, at low levels of demand, output may be less than capacity. Capacity is limited by the stock of tools and simple equipment. Changes in capacity come (after a short wait) from investing in making more tools and equipment at a rate above or below the rate at which they wear out. In India, the principal prototype of this model, investment decisions in this sector are highly responsive to government policy expressed in terms of subsidies, tax concessions, or market protection. Therefore, here, as in the agriculture sector, investment has been treated as a government policy decision, even though most of it is actually carried out by private firms.

The export sector is not formulated as a producing sector with its own capacity and value added, but is simply a means of aggregating the products of two other sectors into a single composite export good.

Consumers' expenditures on personal and professional services do not impinge on an explicit supply function; it is assumed that there is an elastic supply without the necessity for specific capital formation. Only the money flow is accounted for--as consumers' expenditure

and factor income--without identification of a quantity concept or a price index.

Controls

Associated with each domestic sector is a capacity-creation process. In agriculture, nonpowered manufacturing, and public overhead these are directly controlled by government. In the other sectors they are motivated by profit seeking, but entrepreneurs' decisions may be modified by government controls. The controls are introduced in the model as direct upper and lower limitations on construction. Whether they would actually take the form of credit expansion and restriction, subsidies, license requirements, allocation of scarce building materials, or any other form is outside the scope of the model. Also outside the scope of the model are the problems of manipulating finance. Taxes and savings are accounted for, but do not influence the sectoral investment pattern or, in a direct way, the total expenditure, which thus may imply credit expansion and deficit financing. The market mechanisms of the model, nevertheless, realistically produce inflation if expenditures are excessive.

The controls on capacity creation were time-programmed to represent various development plans. The programmed values were sometimes automatically modified, however, in response to inflation or balance of payments deficits. Other tools of government policy

were changes in import tariffs and in the foreign exchange rate.

Completely independent or exogenous quantities were the world

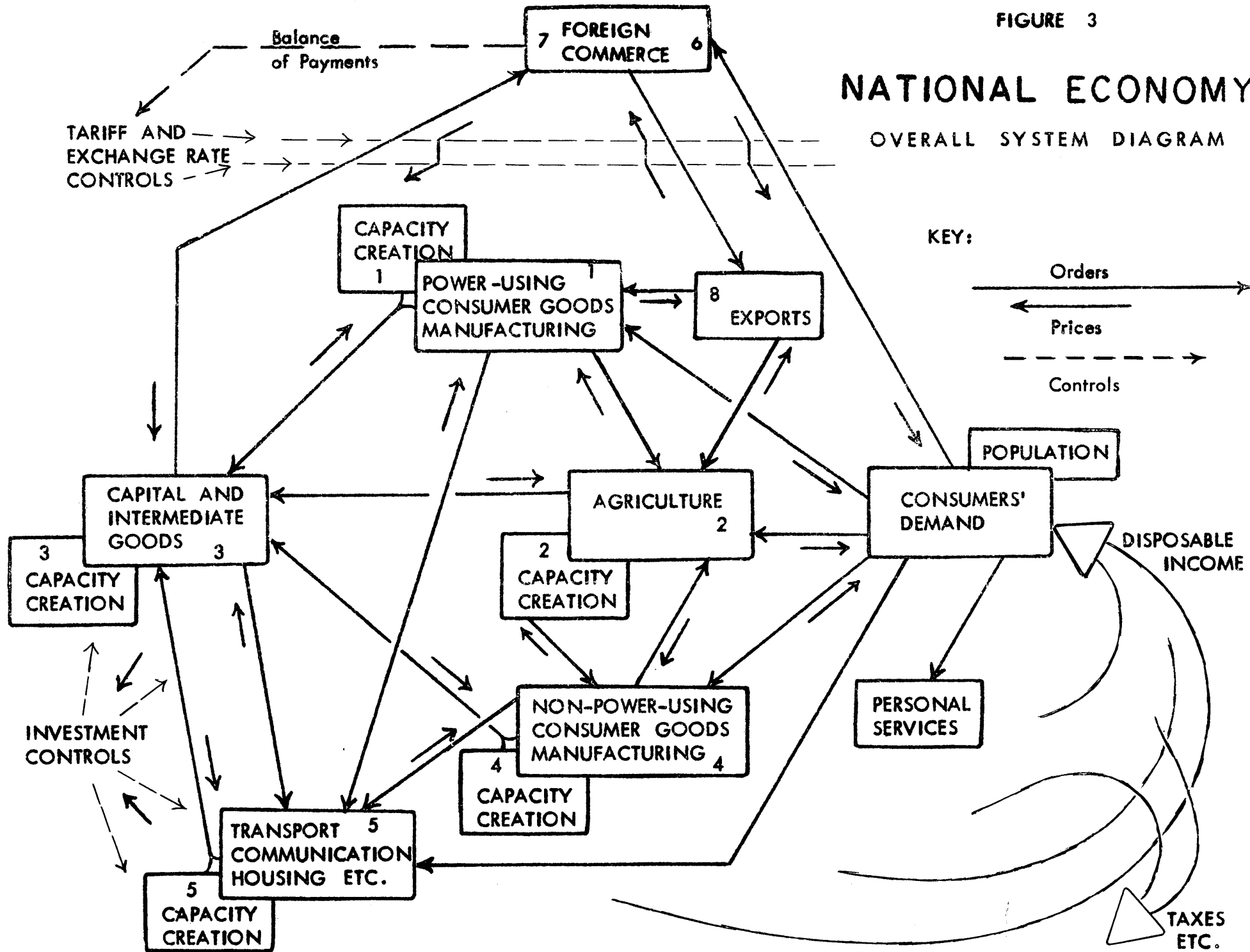
prices of imported goods and the parameters of the demand function

for exports.

FIGURE 3

NATIONAL ECONOMY

OVERALL SYSTEM DIAGRAM



APPENDIX TO CHAPTER 3

To some economists, evidently, a model of an economy means an input-output matrix. It is not our intent here to deny the importance of input-output matrixes; far from it. However, it should be made clear that, in the present study, the input-output relations form only a small part of the system--a necessary part, but certainly no more important than the relations determining final demand or the capital-life-cycle functions, among others. Nevertheless, one of the important improvements over the original model has been the inclusion of more intersectoral demands, and a large part of the research on parameter values went into finding and reconciling information from various sources on the pattern of production and of intersectoral as well as final distribution of outputs.

The results of this study are presented in Figure 4 in value flow terms, and in Figure 5 in terms of the Q_{ij} , K_{ij} , and other coefficients corresponding to Figure 2.

In order to compile the initial values and coefficients of the input-output table corresponding to the model presented here it was necessary to integrate information from a variety of sources. The Q_{ij} elements and the breakdown of Value Added were determined primarily from a 34 X 34 input-output table prepared by the Indian Statistical

Institute.¹ The nature of the aggregation of the thirty-four I.S.I. industry classifications to correspond to our five producing sectors is shown below. Since this table did not explicitly treat interindustry capital component flows and given the lack of published and unpublished material related to the Kij elements the values were established through consultation with members of the India Project of the Center for International Studies. The column vector of investment elements were primarily derived from data supplied by Dr. W. Malenbaum and from V. V. Bhatt.^{2,3} A number of other articles and working papers related to Indian input-output tables were referred to for comparison and substantiation.^{4,5,6}

1. "A Note on Forecasting Net Product of 1953-1954," prepared by the Indian Statistical Institute, (unpublished).

2. This detailed information lies behind Table IA of: W. Malenbaum, "India and China: Contrasts in Development Performance," The American Economic Review, Vol. XLIX, No. 3 (1959), pp. 284-309.

3. V. V. Bhatt, "Savings and Capital Formation," Economic Development and Cultural Change, Vol. VII, No. 3, Part 1 (1959), pp. 318-342.

4. Ajit Biswas, "Input-output Relationships Among Selected Indian Industries," Cambridge, Center for International Studies, Massachusetts Institute of Technology, July 1954, (mimeographed).

5. Studies Relating to Planning for National Development, Working Paper No. 7/RV3.1, Indian Statistical Institute, September 1955.

6. "The Structure of the Indian Economy--The Scope and Possibilities of Input-Output Analysis," Quarterly Economic Report of the Indian Institute of Public Opinion, Vol. 1, No. 3 (1954), pp. 26-27.

AGGREGATION OF 34 INDUSTRIES INTO SIX SECTORS

Power-Manufactured Consumer Goods--Sector 1

(Firms employing more than twenty persons, using power and with capital of more than 500,000 Rs.)

Food, Drink and Tobacco (processing only)
Cotton Textiles
Noncotton Textiles
Leather and Rubber
Paper and Printing
Chemicals
Plantations
Trade and Distribution (split among sectors 1, 2, 4, and 5.)

Agriculture--Sector 2

Agriculture
Animal Husbandry
Jute and Other Fibers
Other Transportation (other than Railways)
Trade and Distribution

Capital and Intermediate Goods--Sector 3

Coke and Coal
All other Mining
Iron and Steel
Nonferrous Metals
Building Materials (large-scale industrial)
Cement
Glass and Ceramics
Engineering

Non-Power-Manufactured Consumer Goods--Sector 4

(Firms employing under fifty persons when employing power or under one hundred persons when not employing power and with capital of less than 500,000 Rs.)

Food, Drink and Tobacco
Textiles
Metalware
Leather
Glass and Ceramics
Building Materials (wood)
Other Production
Trade and Distribution

Public Overhead Services--Sector 5

Electricity
Railways and Communications
Residential Property
Trade and Distribution

Final Demands without Explicit Supply Functions--CVP and GOV

Banking and Insurance
Professional Services
Commerce
Public Administration

FIGURE 4
 INPUT-OUTPUT TABLE (VALUE TERMS)
 (Billions Rs./Year)

	1	2	3	4	5	8	CVP & GOV.	K1	K2	K3	K4	K5	SUB-TOTAL	EXPORTS	INVESTMENT	CONS. & GOV.	P1Q1
1						3.788							3.788			10.010	13.800
2	1.378			0.446		3.230							5.054			58.980	64.030
3	2.894	0.927		0.562	0.506			0.950		1.060	0.040	4.020	10.960				10.960
4									0.810		0.090		0.900			8.010	8.920
5	1.378		0.849	0.446									2.673			7.450	10.110
8														7.018			7.018
CVP & GOV.																10.025	10.025
K1															1.350		
K2															2.700		
K3															1.510		
K4															0.220		
K5															5.020		
SUB-TOTAL	5.650	0.927	0.849	1.454	0.506	7.018		0.950	0.810	1.060	0.130	4.020	23.375				
IMPORTS		2.250	4.177										6.410			2.100	-8.510
VALUE ADDED	8.135	60.853	5.942	7.466	9.605	0.000	10.025	0.410	1.890	0.450	0.090	1.000	105.900	7.018	10.800	96.575	114.393
WAGES	3.588	NO	3.192	7.020	3.286		NO										GNP = 105.900
PROFITS	4.547	BREAKDOWN	2.750	0.446	6.319		BREAKDOWN										
P1Q1	13.800	64.030	10.960	8.920	10.110	7.018	10.025	1.350	2.700	1.510	0.220	5.020					

PART II

DETAILED MODEL FORMULATION

CHAPTER 4

CONSUMERS' JOINT DEMAND FUNCTION

In this chapter, the Consumers' Demand Function is explained and formulated. Population growth is also included here because the assumptions are too simple to warrant a separate section to discuss them and because its sole effect on the system occurs through the demand for food.

At the end of the chapter, an appendix lists all of the pertinent equations and constants exactly as they were coded for a typical computer run. This list, in fact, was printed by machine from punched cards which were part of the input to the IBM 704. Similar lists are appended to the other chapters of this report. The whole set of cards from which these lists were printed constituted the model specification which was fed into the computer for each set of runs together with cards containing the DYNAMO program and other operating instructions.

The Consumers' Joint Demand Function takes as inputs, i.e. independent variables: population, POP; disposable income, YC; and consumer goods market prices, P_i , $i=1,2,4,6$. The outputs, or dependent variables, are: the consumption of food, C2; consumption of two types of services, CV5 and CVP; consumers' savings, SAV; and consumption

of the three nonfood consumer goods, C1, C4, and C6. Demand for each of the two types of services is assumed to have a price-elasticity of unity; thus their prices are not required for determining how much is spent on them. The price of consumers' imports, P6, is determined independently of the quantity consumed. Other prices, which are treated in this chapter as independent variables, are actually determined jointly with expenditures by the interaction between the demand function and the various supply functions (described in later chapters). Thus treating prices as independent variables is not a crucial choice, but only a matter of convenience in formulating this subassembly of the system.

The allocation of disposable income by consumers is treated as if performed in three sequential choices:

First Choice--Food

Consumers are assumed to decide first the quantity of food they wish to consume. Food in this model is defined as unprocessed food or "food on the farm." Thus the consumers' demand for food so defined can be thought of as primarily determined by nutritional requirements and is assumed to be a function only of per capita income deflated by the price of food, P2.

The relation is postulated on a per capita basis as:

$$4.01) \quad q = M + N \sqrt{y_{\text{Food}}}$$

Where: q = quantity of food demanded per capita, $\frac{Q_2}{POP}$.

M, N are parameters.

Y_{Food} = per capita income, measured in food units,

$$\frac{YC}{(POP)(P_2)}$$

P_2 = food price index.

POP = population

YC = lagged (smoothed) value of disposable income, YD .

Thus 4.01 may be rewritten:

$$\frac{Q_2}{POP} = M + N \sqrt{\frac{(YC)}{(POP)(P_2)}}$$

Multiplying by $(POP)(P_2)$ gives aggregate consumption:

$$4.02) \quad C_2 = P_2(Q_2) = M(POP)(P_2) + N \sqrt{(YC)(POP)(P_2)}$$

The form, 4.01, with $M < 0$, was chosen because it implies the hypothesis that the income elasticity of demand for food declines as real income increases (beyond a critical low value where the elasticity is equal to one). This is one form of Engel's Law which empirical studies have confirmed.¹ Below the income level where the elasticity of demand equals one, this formula is not a good fit for

1. Colin Clark, The Conditions of Economic Progress, New York, Macmillan and Co., Ltd., 1957, pp. 445-456; S. J. Prais and H. S. Houthakker, The Analysis of Family Budgets, Cambridge University Press, 1955, Chapter VII and pp. 121-2.

empirical data (nor consistent with Engel's Law). Income that low, however, was avoided in our studies. It would have been below any reasonable subsistence criterion.

Elasticity Relations--Food

Equation 4.02 in quantity terms is:

$$4.03) \quad Q_2 = (M)(POP) + N \sqrt{(POP)(YC/P_2)}$$

The marginal propensity to consume food with respect to income in food units, (YC/P_2) , is:

$$4.04) \quad \frac{\partial(Q_2)}{\partial(YC/P_2)} = (N/2) \sqrt{\frac{(POP)}{(YC/P_2)}}$$

The "real income" elasticity of food demand is thus:

$$4.05) \quad ELY_2 = \frac{\partial(Q_2)}{\partial(YC/P_2)} \cdot \frac{(YC/P_2)}{Q_2}$$

$$4.05) \quad ELY_2 = \frac{(N/2) \sqrt{(POP)(YC/P_2)}}{(M)(POP) + N \sqrt{(POP)(YC/P_2)}}$$

Or in a form more convenient for computational purposes:

$$4.06) \quad ELY_2 = \frac{(N/2) \sqrt{(POP)(YC)(P_2)}}{C_2}$$

1. Although all of the elasticities to be derived here are ceteris paribus, either income or other prices being held constant, the response of the model is determined by the complete or mutatis mutandis elasticities. It is impossible, however, to specify the latter in advance, because they are not independent of the particular dynamic process taking place.

It can be shown that the necessary conditions for:

$$\frac{\partial(\text{ELY}_2)}{\partial(\text{YC}/\text{P}_2)} < 0$$

are: $N > 0$
 $M < 0$

Second Choice--Savings, Services and Nonfood Goods

After allocating the amount to be spent on food, it is assumed that consumers then distribute their remaining income, $(\text{YC}-\text{C}_2)$, in fixed proportions among savings, services and all nonfood consumer goods, CC . The breakdown of CC depends on relative prices and is discussed below under the third choice. Each of the above three is assumed to be unit-elastic with respect to price; hence, it is not necessary to provide a price for any of them. The expenditure relations are:

$$4.07) \quad \text{SAV} = \text{BSAV}(\text{YC} - \text{C}_2)$$

$$4.08) \quad \text{CV}_5 = \text{BV}_5(\text{YC} - \text{C}_2)$$

$$4.09) \quad \text{CVP} = \text{BVP}(\text{YC} - \text{C}_2)$$

$$4.10) \quad \text{CVT} = \text{CV}_5 + \text{CVP}$$

$$4.11) \quad \text{CC} = \text{BC}(\text{YC} - \text{C}_2)$$

$$\text{where } \text{BSAV} + \text{BV}_5 + \text{BVP} + \text{BC} = 1.$$

Third Choice--Nonfood Consumer Goods

The final choice faced by consumers is the distribution of CC among two types of domestic consumer goods and one type of imported consumer goods. This choice differs from the one preceding it in that prices are now explicitly taken into account. The amount consumed of any of the three goods in this group depends not only on its own price but on the prices of the other two goods and on CC. The equation system for the third choice is derived from one developed and used by Richard Stone.¹

$$4.12) \quad C_i = P_i(QZ_i) + B_i \left[CC - \sum_j P_j(QZ_j) \right]$$

$i, j = 1, 4, 6$ subject to the value balance equation:

$$4.13) \quad \sum C_i = CC$$

Or the equivalent condition, $\sum B_i = 1$

Where the B_i 's and QZ_i 's are parameters.

If the QZ 's are all positive, the various goods are complements. To correspond to substitutability among the goods, negative values of the QZ 's have usually been used with this model. This opens up the possibility of a negative value being computed for one of the C_i 's. Since this was not considered permissible, the equations were modified

1. J. R. N. Stone, "Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand," The Economic Journal, September, 1954.

to constrain values to the nonnegative region. By a similar modification, provision was made for simulating a quota restriction on consumer imports.

The equations incorporating these upper and lower limits include some additional symbols, defined as follows:

C_i = Algebraic solution to the demand equation for good i .

MC_i = The maximum value of C_i permitted under rationing or an import quota. This may be either a constant or a variable. In the case of a constant quantity quota, MQ_i , for instance, $MC_i = (P_i)(MQ_i)$.

$$C_i^+ = \begin{cases} MC_i & \text{when } C_i \geq MC_i \\ C_i & \text{when } 0 < C_i < MC_i \\ 0 & \text{when } C_i < 0 \end{cases}$$

$$C_i^- = \begin{cases} C_i & \text{when } C_i < 0 \\ 0 & \text{when } C_i > 0 \end{cases}$$

$$DC_i = \begin{cases} (C_i - MC_i) & \text{when } C_i > MC_i \\ 0 & \text{when } C_i < MC_i \end{cases}$$

The above definitions are such that, under any conditions:

$$4.14) \quad C_i = C_i^+ + C_i^- + DC_i$$

With one or two of the right-hand terms equal to zero.

With these definitions, the following set of equations has the desired properties:

$$4.15) \quad C_i = (P_i)(QZ_i) + B_i \left[CC + \sum C_j^- + \sum DC_j - \sum P_j(QZ_j) \right]$$

$i, j = 1, 4, 6$

Subject to:

$$4.16) \quad \sum B_i = 1$$

And with C_i^+ interpreted as the actual value of consumption.

Proof: If the solution falls between constraints for all goods, $\sum C_i^-$ and $\sum DC_i$ are zero, leaving Equation 4.15 identical to Equation 4.12. If not, the definition of C_i^+ correctly constrains C_i . The total consumption of all the goods is shown to be correct, as follows:

Summing 4.15:

$$\begin{aligned} \sum C_i &= \sum P_i(QZ_i) + \sum B_i \bar{CC} + \sum C_j^- + \sum DC_j \\ &\quad - \sum P_j(QZ_j) \\ i, j &= 1, 4, 6 \end{aligned}$$

Using 4.16 we obtain:

$$\sum C_i = \sum P_i(QZ_i) + CC + \sum C_j^- + \sum DC_j - \sum P_j(QZ_j)$$

But $\sum P_i(QZ_i) = \sum P_j(QZ_j)$, etc., thus:

$$4.17) \quad \sum C_i = CC + \sum C_i^- + \sum DC_i$$

From 4.14 is derived:

$$4.18) \quad \sum C_i^- + \sum DC_i = \sum C_i - \sum C_i^+$$

Combining Equations 4.17 and 4.18 yields:

$$\sum C_i = CC + \sum C_i - \sum C_i^+$$

Hence: $CC = \sum C_i^+$

Thus the total of the C_i^+ values matches the total to be allocated.

Elasticity Relations--Nonfood Goods

Writing 4.12 in terms of Q_i :

$$4.19) \quad Q_i = (Q_{Zi}) + (B_i/P_i) \left[CC - \sum_{j \neq i} P_j(Q_{Zj}) \right]$$

Differentiating partially with respect to P_i :

$$\frac{\partial Q_i}{\partial P_i} = - \frac{B_i}{P_i^2} \left[CC - \sum_{j \neq i} P_j(Q_{Zj}) \right]$$

Price elasticity is thus:

$$EL_{P_i} = \frac{\partial Q_i}{\partial P_i} \cdot \frac{P_i}{Q_i} = \frac{-B_i}{P_i Q_i} \left[CC - \sum_{j \neq i} (P_j)(Q_{Zj}) \right]$$

$$EL_{P_i} = \frac{-1}{1 + \frac{(1-B_i)(P_i)(Q_{Zi})}{B_i \left[CC - \sum_{j \neq i} P_j(Q_{Zj}) \right]}}$$

For computational purposes the following form is more convenient:

$$4.20) \quad EL_{P_i} = \frac{-C_i + (P_i)(Q_{Zi})(1-B_i)}{C_i}$$

It is easily seen that for positive values of B_i the relationship between EL_{P_i} and Q_{Zi} is:

$$|EL_{P_i}| \leq 1 \quad \text{as} \quad Q_{Zi} \geq 0$$

The cross-elasticity relationships are defined as:

$$ELP_{ij} = \frac{dQ_i}{dP_j} \cdot \frac{P_j}{Q_i}$$

From 4.19:
$$\frac{\partial Q_i}{\partial P_j} = \frac{B_i(-QZ_j)}{P_i}$$

and:

$$4.21) \quad ELP_{ij} = \frac{(B_i)(P_j)(-QZ_j)}{(P_i)(Q_i)}$$

Hence for positive B_i :

$$ELP_{ij} \geq 0 \quad \text{as} \quad QZ_j \leq 0$$

To obtain the income elasticity of demand for goods 1, 4, and 6 first recall the relationship:

$$4.11) \quad CC = BC(YC - C2)$$

Then 4.19 becomes:

$$4.22) \quad Q_i = (QZ_i) + (B_i/P_i) \left[BC(YC - C2) - \sum_j P_j(QZ_j) \right]$$

$i, j = 1, 4, 6$

Differentiating partially with respect to (YC) :

$$4.23) \quad \frac{\partial (Q_i)}{\partial (YC)} = \frac{(BC)(B_i)}{P_i} \left[1 - \frac{\partial (C2)}{\partial (YC)} \right]$$

$$= \frac{(BC)(B_i)}{P_i} \left[1 - \frac{N}{2} \sqrt{\frac{(POP)(P2)}{(YC)}} \right]$$

The income elasticity is then obtained using 4.23 and the following definition:

$$\begin{aligned} \text{ELY}_i &= \frac{\partial(Q_i)}{\partial(YC)} \cdot \frac{(YC)}{(Q_i)} \\ &= \left\{ \frac{(BC)(B_i)}{P_i} \left[1 - \frac{N}{2} \sqrt{\frac{(POP)(P_2)}{(YC)}} \right] \right\} \frac{(YC)}{(Q_i)} \\ 4.24) \quad \text{ELY}_i &= \frac{(BC)(B_i)}{(P_i)(Q_i)} \left[YC - \frac{N}{2} \sqrt{(POP)(YC)(P_2)} \right] \end{aligned}$$

Lags in Demand Response

It is assumed that consumers respond with a lag to changes in disposable income, YD, or in prices P1, P4 and P6. The actual inputs to the demand equations involving these four variables are YC, PD1, PD4 and PD6. These two sets of variables are related by the following equations:

$$4.25) \quad d(YC)/dt = (1/AYD)(YD - YC)$$

$$4.26) \quad d(PD_i)/dt = (1/DEL P_i)(P_i - PD_i); \quad i = 1, 4, 6$$

Where AYD and the DELP_i's are exponential lag time constants. These price lags are incorporated by substituting the PD_i's for the P_i's in 4.12. A value of 1.0 is used for AYD, and all DELP_i's equal 0.2.

The choice of a first order exponential form for these lags was dictated by simplicity given the lack of any empirical knowledge of their exact form.

Population

Population, in this model, is not affected by economic variables, but grows exogenously according to the exponential function:

$$4.27) \text{ POP} = (\text{NPOP}) \cdot e^{(\text{PGRA})t}$$

The effect of population on the economic system comes through the demand for food (Equation 4.02), indirectly affecting savings and other demands.

Parameter Values

To generate a solution two types of values must be specified, initial conditions for the variables and specific values for the parameters. The initial values of the variables are given in the input-output table¹ and were not changed during the study. Also the values of many parameters which linearly relate one variable to another are implicit in the input-output table. Parameters of this type in the CJDF are: BVP, BV5, BC and BSAV.

Taking BVP as an example, the equation in which BVP appears is:

$$\text{CVP} = (\text{BVP})(\text{CNF})$$

where: CVP is the consumption of personal services

CNF is disposable income less the value of food consumed.

1. Above, p. 46, Figure 4.

The initial values of CVP and CNF determine BVP and likewise for BV5, BC, and BSAV.

The demand equation for food has two parameters which must be specified. These can be determined by knowledge of any two of the following; initial marginal propensity to consume food, initial average propensity to consume food, or the initial income elasticity of demand for food. We used the average propensity and the income elasticity.

The assumed initial average propensity to consume food, 61.8 per cent, was taken from the input-output table. As a check on this figure there is budget study data obtained from a National Sample Survey¹ (NSS), in which the average propensity to consume food out of total expenditure averaged over all budget classes was found to be 65.4 per cent. Although the difference between these values is not great, one would expect the budget study average to be higher for two reasons. First, the budget study related all expenditure items to total expenditure rather than disposable income as is the case with the average obtained from the input-output table. Second, food as defined in the model input-output table excludes value added in processing while the budget study data includes this as part of the value of food.

1. P. C. Mahalanobis, "Science and National Planning," Sankhya. Vol. 20, Parts 1 and 2, September 1958, pp. 69-106, esp. table (A.10).

No definitive estimate of the income elasticity of demand for food for all India could be found. Estimates of income elasticity derived from National Sample Survey data differ so widely (and with no clear pattern) between income groups or rural and urban consumers that doubt has been expressed on the validity of any averaging of the data.¹ Also definitions of "food" in the estimates differ from the definition used in this model. C. M. Palvia in his econometric model of India, reasoning both from Indian data and data of other countries arrived at a value of 0.8 for the income elasticity of demand for food.² We also used this value for most runs, although other values of the income elasticity of demand for food were also used to determine the sensitivity of the model's behavior to this elasticity. Using for initial values 61.8 per cent as the average propensity to consume foods, and 0.8 as the income elasticity of demand, the values of parameters M and N were determined from equations 4.03 and 4.06. The values are $M = -99.13$ and $N = 16.18$.

The remaining parameters are those of the third choice; they are the B_i 's and Q_{Zi} 's in the equations:

$$4.15) \quad C_i = (P_i)(Q_{Zi}) + B_i \left[\sum_{j=1}^6 C_j + \sum_{j=1}^6 DC_j - \sum_{j=1}^6 P_j(Q_{Zj}) \right]$$

$i, j = 1, 4, 6$

1. K. N. Raj, "Income Elasticity of Demand," Economic Weekly, Annual Number, January 1958, pp. 167-172.

2. C. M. Palvia, An Econometric Model for Development Planning, Institute of Social Studies, 's-Gravenhage, 1953, pp. 31-32.

We have five parameters¹ but only three equations and only two of the equations are independent because $\sum C_i = CC$. To obtain two of the three additional equations which were necessary to allow us to solve for the parameters we arbitrarily specified a set of income elasticities, ELY_1 , 4, and 6. Given ELY_i and using 4.24, B_i were determined. Here again several sets of ELY_i 's were tried.

The QZ_i 's were then determined by specifying one final equation and using the initial conditions for C_1 , 4, and 6 with 4.15. Since the importance of the price elasticity of demand for imports, ELP_6 , was to be studied, several initial values of ELP_6 were arbitrarily established. The corresponding values of QZ_6 were determined using:

$$4.20) \quad ELP_6 = \frac{-C_6 + (P_6)(QZ_6)(1 - B_6)}{C_6}$$

Thus our five independent equations are two of 4.24, two of 4.15 and 4.20.

It should be noted that the values assigned for the ELY_i 's and ELP_6 are in the nature of initial conditions only; that is, the elasticities vary during a solution as prices and income vary.

The population growth rate at present in India is variously estimated from 1.75 per cent per year to somewhat over 2 per cent per year. For most runs in the current program, the exponential growth coefficient, $PGRA$ in Equation 4.27, was made 0.02; for a few runs, 0.03 was used to test the effect of this parameter.

1. Since $\sum B_i$'s = 1, knowledge of any two implies knowledge of the third.

APPENDIX TO CHAPTER 4

DEFINITIONS OF VARIABLES USED IN THE CONSUMERS' JOINT DEMAND FUNCTION.

- ADJCC Intermediate variable used in determining CDA_i , $i = 1, 4, 6$ (billions of rupees per year).
- CC Value of money income allocated for expenditure on Q_1 , Q_4 , and Q_6 (billions of rupees per year).
- CCPQ Intermediate variable used in determining CDA_i , $i = 1, 4, 6$ (billions of rupees per year).
- CDA_i Algebraic solution to the value of Q_i consumed, $i = 1, 4$ (billions of rupees per year)¹.
- CDA_6 Algebraic solution to the value of Q_6 consumed after adjustment for quota restriction, if any (billions of rupees per year).
- CDB_6 Algebraic solution to the value of Q_6 consumed before adjustment for quota restriction, if any (billions of rupees per year).
- $CDELi$ Intermediate variable used to define $ELPi$, $i = 1, 4, 6$ (billions of rupees per year).
- CDi Positive values only of CDA_i , $i = 1, 4, 6$ (billions of rupees per year)¹.
- CNF Value of nonfood consumption (billions of rupees per year).
- CVP Value of personal services consumed (billions of rupees per year).
- CVT Total value of services consumed (billions of rupees per year).
- CV5 Value of sector 5 services consumed (billions of rupees per year).
- C_i Value of Q_i consumed, $i = 1, 2, 4, 6$ (billions of rupees per year).¹
- $CiNEG$ Negative values of CDA_i , $i = 1, 4, 6$ (billions of rupees per year).¹
- $C2M$ Intermediate variable used in determining $C2$.
- $C2N$ Intermediate variable used in determining $C2$.
- DC_6 The amount by which the desired C_6 expenditure exceeds the quota limit (billions of rupees per year).

1. See note on next page.

ELPAi	Intermediate variable used in determining ELPi, $i = 1,4,6$.
ELPi	Price elasticity of demand for Q_i , all other prices and money income held constant, $i = 1,4,6$ (nondimensional).
ELYAi	Intermediate variable used in determining ELYi, $i = 1,4,6$.
ELYBi	Intermediate variable used in determining ELYi, $i = 1,4,6$.
ELYi	Elasticity of demand for Q_i with respect to money income, $i=1,2,4,6$ (nondimensional).
PDi	Lagged value of P_i , $i = 1,4,6$ (billions of rupees per quant).
PGR	Intermediate variable used in determining POP.
POP	Population (billions of people).
RPDi	Rate of change of PDi , $i = 1,4,6$ (rupees per quant per year)
RYC	Rate of change of YC (billions of rupees per year per year).
YC	Lagged value of YD (billions of rupees per year); disposable income.
YCPP2	Intermediate variable used in determining C_2 .

Note: Relation of DYNAMO symbols to those in text

For clarity of exposition a mnemonic notation was used in the exposition of the third consumers' choice; the DYNAMO variables which correspond to those used in the text are listed below:

<u>Text Variable</u>	<u>DYNAMO Equivalent, using lagged prices</u>
C_i	CDAi
C_i^+	CDi
C_i^-	CiNEG

DEFINITIONS OF PARAMETERS USED IN THE DEMAND FUNCTION

- AYD Time constant relating YC to YD (years).
- BC Proportion of CNF expended on Q1, Q4, and Q6 (nondimensional).
- Bi Parameter in the demand equation for Qi, $i = 1, 4, 6$ (nondimensional).
- BSAV Proportion of CNF saved (nondimensional).
- BVP Proportion of CNF expended on personal services (nondimensional).
- BV5 Proportion of CNF expended on social overhead services (nondimensional).
- M Parameter in the demand equation for C2.
- N Parameter in the demand equation for C2.
- NPOP Initial value of POP (billions of people).
- PRGA Rate of population growth (proportion per year).
- PiDEL Time constant relating PDi to Pi, $i = 1, 4, 6$ (years).
- QZi Parameter in the demand equation for Qi, $i = 1, 4, 6$ (nondimensional).

CONSUMERS DEMAND FUNCTION (AND POPULATION)

POPULATION EQUATIONS

28A POP.K=(NPOP)EXP(PGR.K) EH6200
 12A PGR.K=(PGRA)(TIME) EH6201

INITIAL CONDITIONS AND CONSTANTS

C NPOP=.357/PGRA=.0200 EH6202

CONSUMPTION FUNCTION EQUATIONS

1L YC.K=YC.J+(DT)(RYC.JK+0) EH6298
 21R RYC.KL=(1/AYD)(YD.K-YC.K) EH6299
 7A C2.K=C2M.K+C2N.K EH6300
 13A C2M.K=(-M)(POP.K)(P2.JK) EH6301
 30A C2N.K=(N)SQRT(YCPP2.K) EH6302
 13A YCPP2.K=(YC.K)(POP.K)(P2.JK) EH6303
 7A CNF.K=YC.K-C2.K EH6304
 7A CVT.K=CV5.K+CVP.K EH6305
 12A CVP.K=(BVP)(CNF.K) EH6306
 12A CV5.K=(BV5)(CNF.K) EH6307
 12A CC.K=(BC)(CNF.K) EH6308
 1L PD1.K=PD1.J+(DT)(RPD1.JK+0) EH6309
 21R RPD1.KL=(1/P1DEL)(P1.JK-PD1.K) EH6310
 1L PD4.K=PD4.J+(DT)(RPD4.JK+0) EH6311
 21R RPD4.KL=(1/P4DEL)(P4.JK-PD4.K) EH6312
 1L PD6.K=PD6.J+(DT)(RPD6.JK+0) EH6313
 21R RPD6.KL=(1/P6DEL)(P6.JK-PD6.K) EH6314
 10A ADJCC.K=CC.K+C1NEG.JK+C4NEG.JK+C6NEG.JK+DC6.JK+0 EH6315
 16A CCPQ.K=(ADJCC.K)(1)+(-PD1.K)(QZ1)+(-PD4.K)(QZ4)+(-PD6.K)(QZ6) EH6316
 15A CDA1.K=(PD1.K)(QZ1)+(B1)(CCPQ.K) EH6317
 51A CD1.K=CLIP(CDA1.K,0,CDA1.K,0) EH6318
 7R C1NEG.KL=CDA1.K-CD1.K EH6319
 44A C1.K=(P1.JK)(CD1.K)/PD1.K EH6320

15A	$CDA4.K = (PD4.K)(QZ4) + (B4)(CCPQ.K)$	EH6321
51A	$CD4.K = CLIP(CDA4.K, 0, CDA4.K, 0)$	EH6322
7R	$C4NEG.KL = CDA4.K - CD4.K$	EH6323
44A	$C4.K = (P4.JK)(CD4.K) / PD4.K$	EH6324
15A	$CDB6.K = (PD6.K)(QZ6) + (B6)(CCPQ.K)$	EH6325
51A	$CDA6.K = CLIP(MC6.K, CDB6.K, CDB6.K, MC6.K)$	EH6338
7R	$DC6.KL = CDB6.K - CDA6.K$	EH6339
51A	$CD6.K = CLIP(CDA6.K, 0, CDA6.K, 0)$	EH6326
7R	$C6NEG.KL = CDA6.K - CD6.K$	EH6327
44A	$C6.K = (P6.JK)(CD6.K) / PD6.K$	EH6328

INITIAL CONDITIONS AND CONSTANTS

6N	$YC = 95.3$	EH6009
6N	$PD1 = 1.0$	EH6329
6N	$PD4 = 1.0$	EH6330
6N	$PD6 = 1.0$	EH6331
6N	$C1NEG = 0.0$	EH6332
6N	$C6NEG = 0.0$	EH6333
6N	$C4NEG = 0.0$	EH6334
6N	$DC6 = 0$	EH6340
C	$BVP = .101 / BV5 = .205 / BSAV = .140 / BC = .554 / M = 099.126 / N = 16.179 \quad ELY2 = .8$	EH6335
C	$P1DEL = .2 / P4DEL = .2 / P6DEL = .2 / AYD = 1.0$	EH6336
C	$B1 = .52 / B4 = .37 / B6 = .11 / QZ1 = 5.6498 / QZ4 = 4.9047 / QZ6 = 1.1798$	EH6337

ELASTICITY EQUATIONS

20S	$ELP1.K = ELPA1.K / CDEL1.K$	EH6450
49S	$CDEL1.K = SWITCH(1.0, CD1.K, CD1.K)$	EH6451
17S	$ELPA1.K = (-CD1.K)(1)(1) + (PD1.K)(QZ1)(1) + (-PD1.K)(QZ1)(B1)$	EH6452
20S	$ELP4.K = ELPA4.K / CDEL4.K$	EH6453
49S	$CDEL4.K = SWITCH(1.0, CD4.K, CD4.K)$	EH6454
17S	$ELPA4.K = (-CD4.K)(1)(1) + (PD4.K)(QZ4)(1) + (-PD4.K)(QZ4)(B4)$	EH6455
20S	$ELP6.K = ELPA6.K / CDEL6.K$	EH6456
49S	$CDEL6.K = SWITCH(1.0, CD6.K, CD6.K)$	EH6457
17S	$ELPA6.K = (-CD6.K)(1)(1) + (PD6.K)(QZ6)(1) + (-PD6.K)(QZ6)(B6)$	EH6458

12S	$ELY1.K = (ELYA1.K) (ELYB1.K)$	EH6459
15S	$ELYA1.K = (1) (YC.K) + (-0.5) (C2N.K)$	EH6460
44S	$ELYB1.K = (B1) (BC) / CDEL1.K$	EH6461
12S	$ELY4.K = (ELYA4.K) (ELYB4.K)$	EH6462
15S	$ELYA4.K = (1) (YC.K) + (-0.5) (C2N.K)$	EH6463
44S	$ELYB4.K = (B4) (BC) / CDEL4.K$	EH6464
12S	$ELY6.K = (ELYA6.K) (ELYB6.K)$	EH6465
15S	$ELYA6.K = (1) (YC.K) + (-0.5) (C2N.K)$	EH6466
44S	$ELYB6.K = (B6) (BC) / CDEL6.K$	EH6467
44S	$ELY2.K = (0.5) (C2N.K) / C2.K$	EH6468

CHAPTER 5

INDUSTRIAL PRODUCTION AND PUBLIC OVERHEAD CAPITAL

A. POWER-MANUFACTURED CONSUMER GOODS (SECTOR 1)

General

This sector represents the modern capital-intensive power-using consumer goods manufacturing activity of the economy. Initially the sector contributes relatively little towards the National Product with over ninety per cent of its activity related to the production of cotton textiles and food processing. Included in the product mix are such other goods as noncotton textiles, leather and rubber goods, paper and printing, and plantation crops. Its output goes to consumers and into the export product.

The rationale for including plantations in this sector and the particular division between unprocessed (on the farm) food and the processing itself should be mentioned at this point. Plantations, representing mainly the output of tea, were included in this sector rather than in the Agriculture Sector in recognition of its relatively high capital to output ratio and long capital gestation time. The use of scientific methods and the mechanization of procedures is in definite contrast with other agricultural activity. In relation to food, only the processing of processed foods is included in the output mix of this sector. The processing and the raw food are treated as

separate final consumers' goods; the raw food being purchased directly from the Agricultural Sector and the processing directly from this sector. This distinction is made in order to explicitly recognize differences in the income elasticity of demand for raw foods as contrasted to that of processed foods.

The Short-Run Supply Function

For each of the producing sectors of the economy there exists a short-run supply function. This set of supply functions interacts with the Consumers Joint Demand Function and the export and intermediate goods demands to determine the various prices and quantities.

Prices and quantities change with time, however, as income and intermediate goods demand changes and as the short-run supply curves are shifted by changes in capacity, wages, and costs of intermediate materials. Each producing sector is treated as far as possible as an integrated industry, ranging from the owners of natural resources to the transporters and retailers of the final product. Exceptions to this are necessary for intermediate products that are imported or transferred between sectors.¹

Nominal sectoral capacity, QB_1 , is determined by the physical stock of capital, KB_1 , which is measured in units of "standard" plants. Each standard plant can produce one "quant" of output per year, thus by definition the physical capital to output ratio, KB_1/QB_1 , is equal to unity. When output, Q_1 , is less than nominal capacity it is produced by the most efficient plants, where efficiency (to be discussed in the following paragraph) is measured by

1. Holland, Op. cit., p. 54.

variations in the labor to output ratio for different "standard" plants. In this region ($Q_1 \leq KB_1$), costs of production alone determine the shape of the short-run supply curve.

Production costs are composed of direct labor costs and intermediate goods costs. Direct labor costs are the product of the sectoral wage rate, W_1 , and the labor to output ratio, LP_{QQ1} , of the marginal plant at the current rate of output. Determination of the wage rate will be discussed in a succeeding section. The labor to output ratio for a particular plant is a function of the state of technology at the time that plant was built. Technological progress in turn is a function of capital creation. The assumption used here is that the experience gained in research and development, design and operation of each new plant introduces labor saving innovation in the design and operation of the succeeding plant. The effect of technological progress on the labor to output ratio of the newest plant coming into production is:

$$5.01) \quad LP_{QM1} = LP_{QN1} / \left[1 + (MU_1)(KP_1) \right] \quad \text{Labor units/Quant}$$

Where LP_{QN1} was the labor to output ratio of the newest plant in production at time zero and

$KP_1 = \int_0^t (RK_{P1}) dt$ is the total number of new plants which have since come into production.

The labor to output ratio of the least efficient plant called into active production, LP_{QQ1} , becomes:

$$5.02) \quad LPQQ1 = LPQM1 / [\bar{L} + (MU1)(KPl - Q1)] \quad \text{Labor units/Quant}$$

Intermediate goods cost per unit of Q1 is the sum of the product of factor costs, Pi, and the input-output coefficients, Qil, such that the total intermediate goods cost is:

$$5.03) \quad \sum_{i=2,3,5} (Pi)(Qil) \quad \text{Billion Rs./Quant}$$

Total variable cost, PA1, for the marginal plant then is the intermediate goods cost reflected in equation 5.03 plus the labor to output ratio of the marginal plant reflected in equation 5.02 multiplied by the appropriate wage rate:

$$5.04) \quad PA1 = \sum_{i=2,3,5} (Pi)(Qil) + (W1)(LPQQ1) \quad \text{Billion Rs./Quant}$$

$$P1 = PA1 \text{ for } Q1 \leq QB1$$

Thus the short-run supply curve may be viewed as a continuum of variable costs of plants in the sector, the newest plant (the most efficient) being on the extreme left and the oldest plant (the least efficient) on the extreme right at QB1. The upward concavity of the short-run curve is a reflection of equation 5.01 for LPQM1.

For outputs which exceed nominal capacity the slope of the short-run curve becomes much steeper allowing for only small additions to output at a rapidly increasing price per unit. This additional increment, PEX1, to the pricing equation is defined by the following set of equations:

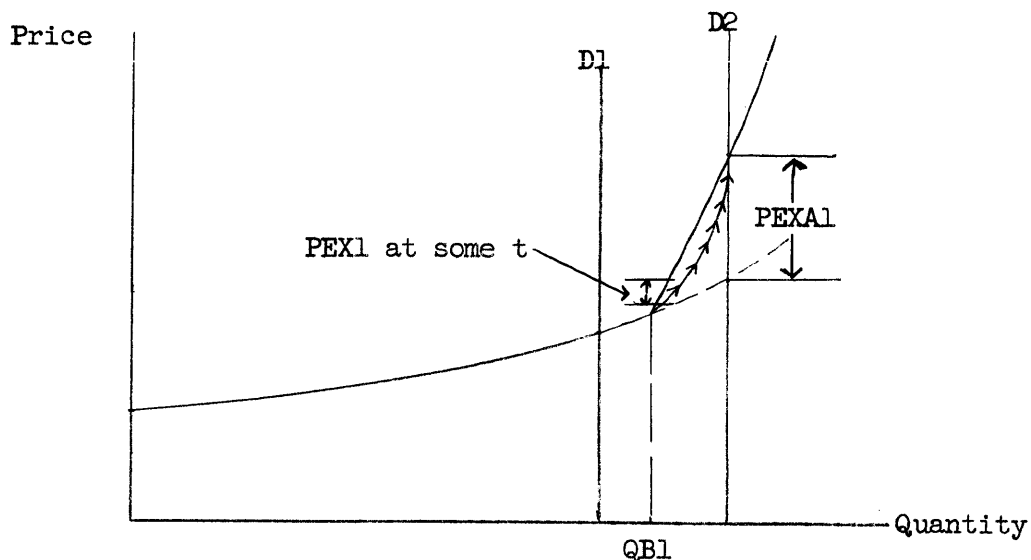
$$5.05) \quad d(\text{PEX1})/dt = (1/\text{OMEG1})(\text{PEXA1}-\text{PEX1}) \text{ for } Q1 > QB1$$

Billion Rs./Quant/Yr.

$$5.06) \quad \text{PEXA1} = (\text{ZETA1})(Q1-QB1)$$

$$5.07) \quad \text{ZETA1} = (\text{PA1})(J1)/QB1$$

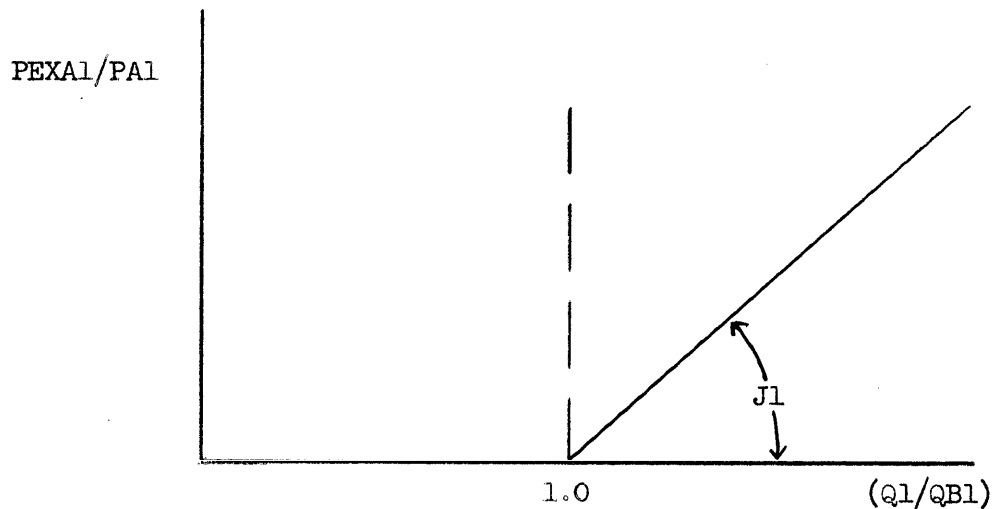
The above set of equations embodies two separate concepts whose rationale follow. The response of PEX1 to changes in demand which are greater than QB1 is damped by use of the exponential lag form of equation 5.05, the degree of damping in years being established by the time constant OMEG1. Below is a diagrammatic interpretation of this type of response. The arrowed line illustrates the behavior of PEX1 following a shift of demand from D1 to D2. The particular



shape of the adjustment path depends of course on the elasticity of the demand curve. The second concept, that of the particular slope

of the off-vertical segment is contained in equations 5.06 and 5.07 above. The slope is a function both of the overcapacity situation of the sector and of production costs. The ratio of PEX1 to the cost-determined price is proportional to the percentage of overcapacity utilization, where J1 is a dimensionless proportionality constant.

The diagram below represents this relationship.



The complete pricing equation becomes:

$$5.08) \quad P_1 = P_{A1} + PEX_1 \quad \text{Billion Rs./Quant}$$

Where $PEX_1 = 0$ for $QB_1 \geq Q_1$

Given the assumed absence of inventory changes, the quantity produced is equal to the quantity demanded.

$$5.09) \quad Q_1 = QC_1 + (QEX_8)(Q_{18}) \quad \text{Quants/yr.}$$

Where QC_1 is domestic consumers' demand and the second term is the portion of export demand filled by sector 1, as explained in Chapter 7--Foreign Sector.

The three following sections describe the dynamic mechanisms of wage rate changes, investment, and the life cycle of capital. Figure 6, on page 76a, shows how the short-run supply and demand balance influences these mechanisms and how they eventually, by altering costs and capacity, shift the short-run supply curve.

Profits and the Wage Rate

It is postulated that changes in the wage rate are a function of the average net profit in the sector, $PIAV_1$.

$$5.10) \quad PIAV_1 = P_1 - \left[\sum_{i=2,3,5} (P_i)(Q_{i1}) + (W_1)(LPQ_{A1}) \right] - (O_{H1})(PK_1)$$

Billion Rs./Quant

The product of O_{H1} , the overhead per unit of investment cost, and PK_1 , the investment cost per unit of output capacity, forms a deduction for overhead costs in determining the appropriate average profit figure.

Note that the labor cost used in the above equation, LPQ_{A1} , is the average of costs for all producing firms. It is determined as follows:

$$5.11) \quad LPQ_{A1} = 1/Q_1 \left[\int_0^{Q_1} (LPQ_{Q1})(dQ) \right]$$

$$= - \int (LPQ_{N1}) / (M_{U1})(Q_1) \int \left\{ \log \left[1 + (M_{U1})(K_{P1} - Q) \right] \int_0^{Q_1} \right\}$$

$$= \int (LPQ_{N1}) / (M_{U1})(Q_1) \int \log \left\{ \left[1 + (M_{U1})(K_{P1}) \right] / \left[1 + (M_{U1})(K_{P1} - Q_1) \right] \right\}$$

Labor in this sector and in the capital-goods sector is unionized. Whenever average net profit in one of these sectors is positive, the unions are able to force wages in the sector gradually upwards. . . . Also, mobility between these two industrialized sectors has a tendency to equalize wages by raising those which are lower.¹

The two effects are additive such that:

$$5.12) \quad d(W1)/dt = \left[(WC1/WD1)(PIAV1/LPQA1) + (1/MD1)(W3 - W1) \right]$$

subject to the restriction that $d(W1)/dt \geq 0$.

When the formula above would yield a negative value, unions cannot negotiate raises, but are assumed to be able to prevent wages from being cut. Hence the restriction against negative values.²

In order to determine "business savings" the gross flow of sectoral profits, PROF1, is required. This can be obtained directly from Equation 5.10 above. Since overhead costs do not enter into this gross flow we need only omit the overhead cost element and multiply the remainder of the equation by Q1.

$$5.13) \quad \text{PROF1} = \left[P1 - \sum_{i=2,3,5} (Pi)(Qi1) - (W1)(LPQA1) \right] (Q1)$$

Billion Rs./yr.

For definitions and use of the terms "business savings" and the gross profit concept as used in this model see Chapter 8, dealing with the Income Accounts.

1. Ibid., pp. 79-80.

2. Loc. cit.

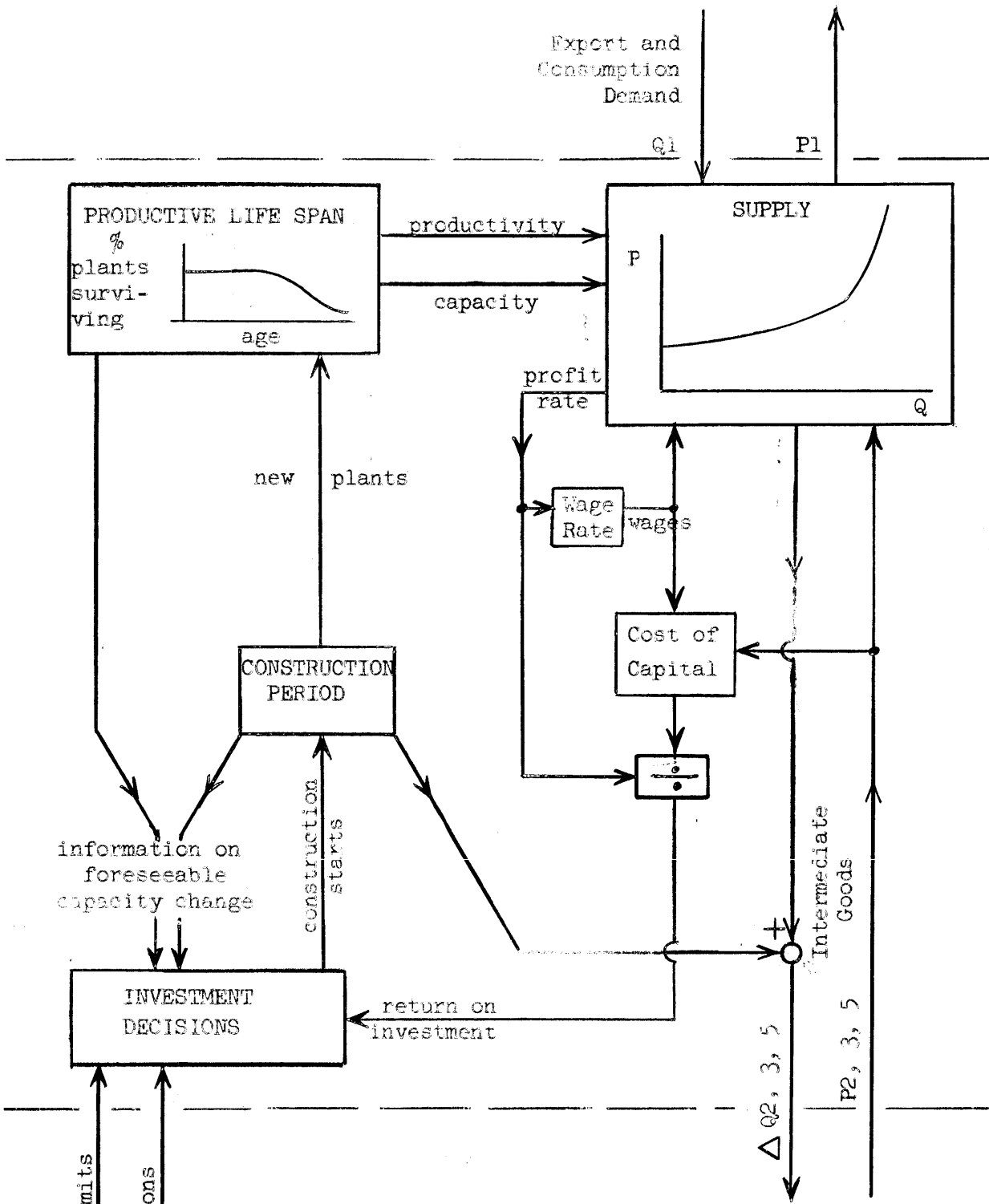


FIGURE 6

POWER-USING CONSUMER GOODS
 MANUFACTURING -- SECTOR 1

Capacity Changes

The variable RKS_1 , to be developed in the following section, represents the actual time rate of starting new capital projects in plants per year. The elapsed time necessary for a project to be translated into a productive facility is termed the "gestation" period. The gestation period is formulated in two parts. The first is a finite time, $(G_1 - E_1)$ years, postulated as the minimum required for the completion of any single project. The second is a statistically-dispersed time period such that the average gestation time for all projects exceeds the minimum value by E_1 years. The average gestation time for all projects is therefore G_1 years. The rate at which new plants are completed, leaving the gestation phase and augmenting the productive capacity of the sector, is designated RKP_1 . The dispersion of individual projects' gestation times about the average value of G_1 years is represented by making RKP_1 the output of a third order exponential lag with time constant E_1 , following a discrete delay, $(G_1 - E_1)$, with RKS_1 as the input.^{1,2}

1. The dispersion is characterized by the following equations:

$$5.14) \quad \sum_{j=0}^3 \binom{3}{j} (E_1/3)^j (d^j RKP_1 / dt^j) = (RKP_1)_t \quad \text{Plants/yr.}$$

$$5.15) \quad (RKP_1)_t = (RKS_1)_{(t - (G_1 - E_1))} \quad \text{Projects/yr.}$$

In the future for the sake of simplicity the general form of Equation 5.14 will be represented by its DYNAMO notation of:

This dispersion of the gestation time allows for such factors as the diversified nature of the projects under construction and the variation of skills among designers and contractors, etc. The end result then is a function which, although establishing an average gestation time for all projects initiated in the sector, leaves the individual projects' gestation time as finite but uncertain. A graphical representation of this mechanism for a step input in $RKSl$ at time zero is shown in the next diagram.

The total number of future plants in the gestation phase is:

$$5.16) \quad KG1_t = KG1_{t=0} + \int_0^t (RKSl - RKPl) dt \quad \text{Plants}$$

and given the cost per plant ($PK1$), the monetary flow of gross investment in sector 1 can be obtained from 5.16 as:

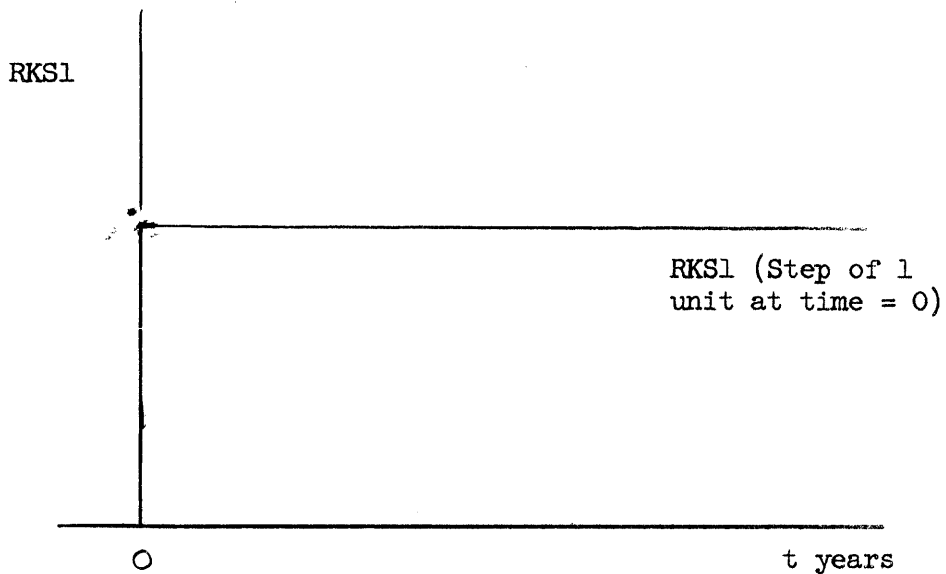
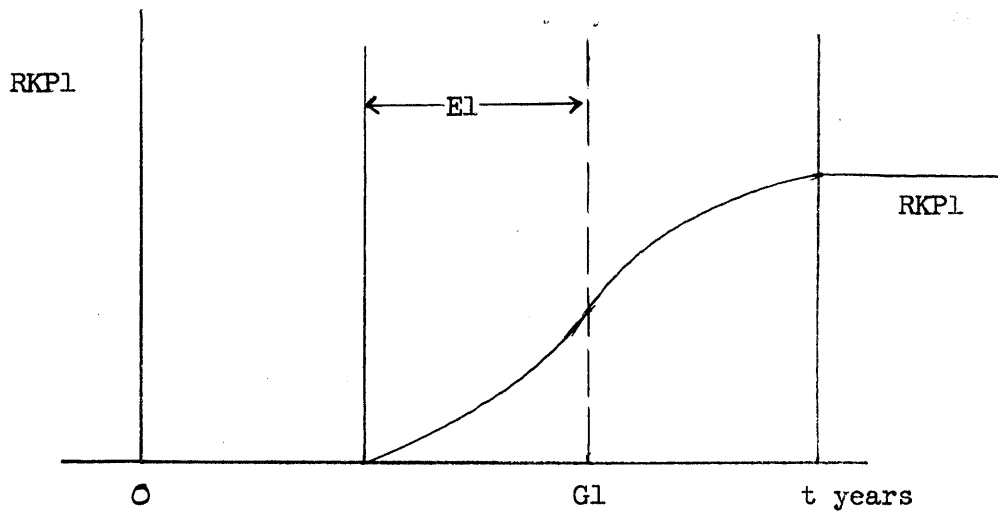
$$5.17) \quad INV1 = (KG1)(PK1/G1) \quad \text{Billion Rs./yr.}$$

$$\text{OUTPUT} = \text{DELAY3}(\text{INPUT}, \text{AVG. DELAY})$$

In this form, Equation 14 is represented as:

$$5.14) \quad RKPl = \text{DELAY3}(RKPA1, E1)$$

2. For a thorough analysis of this type of equation see: George Hadley, Trivial Properties of Exponential Delays, Industrial Dynamics Research Memo D-28, M.I.T. School of Industrial Management, 1959.



Each newly created plant has the capability of being fully productive throughout a finite but uncertain lifetime. Analytically the situation is similar to that which was used above in defining the gestation phase. We define a minimum lifetime, $(D1 - A1)$ years, and an average lifetime of $D1$ years. "Attrition" is then dispersed about the average, $D1$ years, by a third order lag with a time constant of

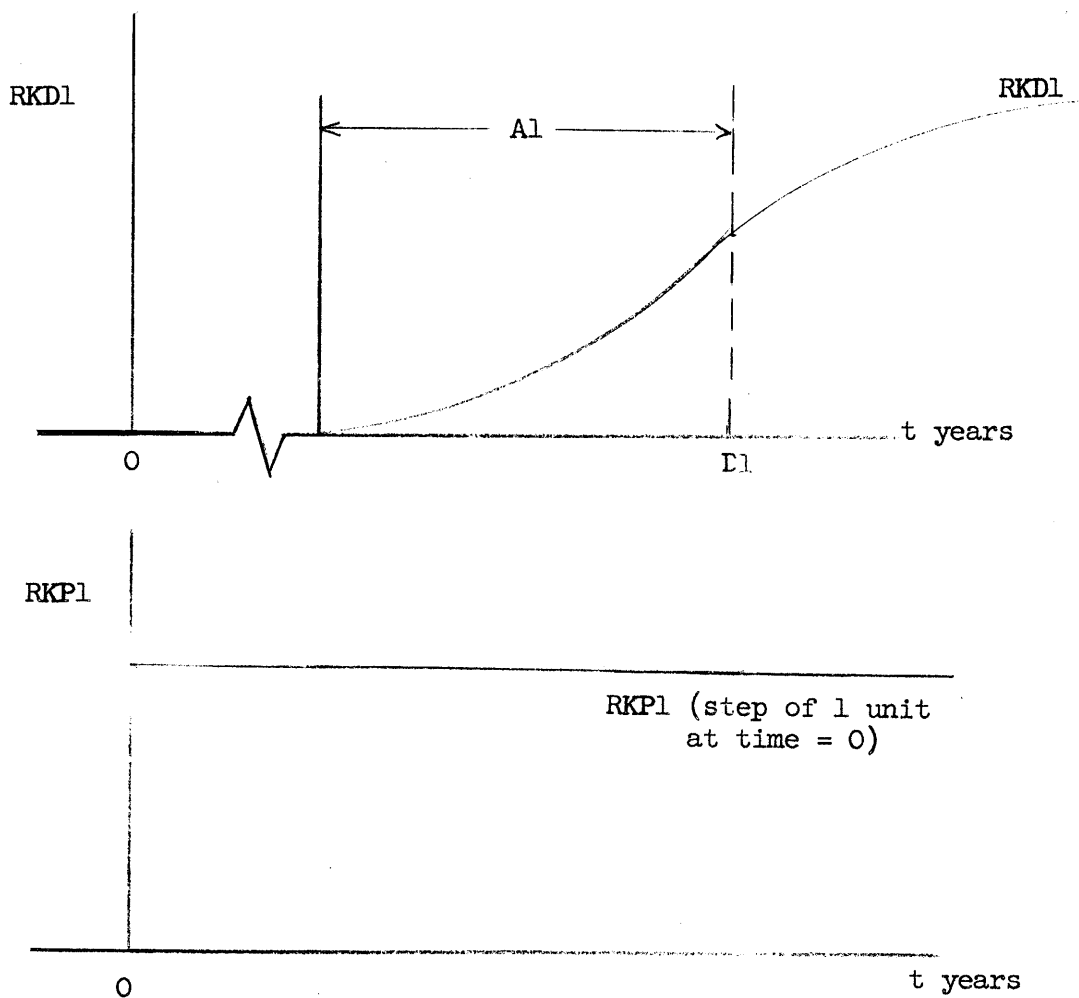
A_1 years. The rate of attrition, RKD_1 , in plants per year therefore is:

$$5.18) \quad RKD_1 = \text{DELAY3}(RKE_1, A_1) \quad \text{Plants/yr.}$$

where:

$$5.19) \quad RKE_1_t = RKPl(t - (D_1 - A_1)) \quad \text{Plants/yr.}$$

The graphs below depict the attrition curve which would necessarily follow a hypothetical step in $RKPl$.



Two additional variables which are auxiliary to the above analysis will be needed for use in the following section dealing with the investment decision function. The time profile of plants which will undergo attrition in G_1 years, $RKRL$, is derived in the same manner as $RKDL$ above:

$$5.20) \quad RKRL = \text{DELAY3}(RKQ1, A1) \quad \text{Plants/yr.}$$

where:

$$5.21) \quad RKQ1_t = RKPL(t - (D1 - G1 - A1)) \quad \text{Plants/yr.}$$

Note that $RKDL$ is nothing other than the time profile of $RKRL$ delayed in time by G_1 years. The total number of plants due to expire within the next G_1 years comes directly from the above in the form:

$$5.22) \quad KE1 = KE1_{t=0} + \int_0^t (RKRL - RKDL) dt \quad \text{Plants}$$

The Investment Decision Function

The investment behavior of private entrepreneurs in this sector--as in the Capital and Intermediate Goods sector--is postulated as being closely geared to their expectations about the future rate of return on investment capital, $XR1$. The relevant net profit rate then is that associated with the newest firm in existence, $P1MA1$, which is:¹

1. This equation is derived in the same manner as Equation 5.10 above for $PIAV1$. Here, however, the relevant labor to output ratio is that for the most efficient plant, $LPQM1$.

$$5.23) \quad PIM1 = P1 - \left[\sum_{i=2,3,5} (Pi)(Qil) + (W1)(LPQML) \right] - (OHL)(PK1)$$

Billion Rs./Quant

If this is interpreted as the potential profit rate on output to be produced with new capital (with neutral expectations), then it can be expressed as a potential rate of return on capital by dividing by the cost at current prices of the capital required for a unit of output flow. Since $(KBL/QBL) = 1$, the divisor . . . is simply $PK1$.¹

This is then adjusted by an increment, $DELH1$, for optimism or pessimism concerning future expectations.² Thus the expected return on investment capital becomes:

$$5.24) \quad XR1 = (PIM1)/(PK1) - (DELH1) \quad \frac{\text{Rs./yr.}}{\text{Rs.}}$$

The aggregate of investment decisions in this sector depends partly on this expected return, $XR1$, partly on financial factors, and partly on government intervention. In this formulation, the first step is to establish what level of capital formation entrepreneurs would undertake if credit were unlimited at the current interest rate and if no special incentives or restraints were in effect. This level may then be undertaken, or reduced by limited credit or license requirements, or increased by government subsidy or direct investment.³

Assuming no credit limitations or government intervention the private entrepreneurs plan in terms of a hypothetical "target" increment, DK^t , of capital proportional to $XR1$.

1. Holland, Op. cit., p. 65.

2. $DELH1$ is negative to exhibit optimism and positive to exhibit pessimism.

3. Holland, Op. cit., p. 66.

$$5.25) \quad DK^t = (GAMM1)(XR1) \quad \text{Plants}$$

$$\text{Where } (GAMM1) = \left[\frac{NGAM1 + (GRTH1)(KB1)}{J} \right]^1$$

This target increment does not affect productive capital until one gestation period has transpired. To translate DK^t into a "wanted" increment of capital one gestation period in the future entrepreneurs realize that an adjustment must be made for capacity changes (already committed) which will take place during that period. The entrepreneur must adjust for the level of capital presently in the gestation phase, $KG1$, and for the level of capital which will inexorably expire during the same period, $KE1$.² The wanted increment therefore becomes:

$$5.26) \quad DK^w = DK^t - (ALFA1)(KG1) + KE1 \quad \text{Plants}$$

Where, ". . . ALFA1 is a parameter whose deviation from a value of 1.0 indicates the extent to which individual entrepreneurs' allowances for others' projects add up to more or less than the actual total of such projects."³

The entire "wanted" increment cannot be initiated simultaneously by entrepreneurs, but only at a finite rate, $RKS1$, plants per year.

If each one were trying to hold capital at a constant level, he would start new projects at exactly the rate (however it might fluctuate) that old capital in his firm reaches such an age that it would expire one gestation period later.⁴

1. This form postulates that a relationship exists--for any given $(XR1)$ --between the desired target increment and the existing level of capacity.

2. $(KG1)$ and $(KE1)$ were derived in the previous section as Equations 5.16 and 5.22.

3. Holland, *Op. cit.*, p. 67.

4. Ibid.

This rate at which capital is reaching the age where replacement will be required in one gestation period is defined as RK_{R1} and was derived in the previous section. Given that an equilibrium situation of constant capital stock would exist when RK_{S1} is equal to RK_{R1} , then the difference existing at any point in time between these two rates will be observed one gestation period in the future as the rate of change of capital stock, K_{B1} . This can be seen from:

$$5.27) \quad (RK_{S1} - RK_{R1})_t = (RK_{P1} - RK_{D1})_{t+G1} = d(K_{B1})/dt_{t+G1}$$

Plants/yr.

The aggregate effect of entrepreneurs' responses is postulated to be to adjust DRK_{S1} --the desired rate of starting new capital projects--such that $(DRK_{S1} - RK_{R1})$ is proportional to the wanted increment, DK^W .¹ The complete investment decision function thus becomes:

$$5.28) \quad DRK_{S1} = RK_{R1} + \lambda_{AMD1} \left[(GAMM1)(X_{R1}) - (ALFAL)(K_{G1}) + (KE1) \right]$$

Plants/yr.

The Cost of Capital

Capital formation. . . requires machinery and certain construction and building materials which are manufactured

1. A positive value of DRK_{S1} is a desired or intended rate of starting new capital projects which is equal to the actual rate, RK_{S1} , only if the previous assumption concerning the lack of credit limitations and government intervention holds true. When this assumption is not fulfilled, DRK_{S1} will be altered in accordance with the criteria set up in Chapter 9 dealing with controls.

by industries of limited capacity. To the extent that foreign-exchange policy allows, the limited domestic supply may be supplemented by imports.¹

The cost of machinery and building materials, P_3 , is determined in sector 3 and when multiplied by the quantity of such goods required per plant constructed, $(NCOR1)(K31)$, determines the cost of capital goods per plant.² "Capital creation also uses labor of the same degree of skill as those who make the product of sector 1, paid at the same wage rate, W_1 ."³ The labor requirement per plant constructed is defined as $(NCOR1)(KL1)$, with the total labor cost being the product of this and the wage rate. The total cost per plant, PK_1 , then is:⁴

$$5.29) PK_1 = (NCOR1) [(KL1)(W_1) + (P_3)(K31)] \quad \text{Rs./Plant}$$

The Capital to Output Ratio

As formulated in the model the physical capital to output ratio is defined as equal to unity. In value terms then, the capital to output ratio is merely the ratio of capital cost, PK_1 , to the output price, P_1 . Given that the capital to output ratio is a variable, only the initial condition, $NCOR_1$, can be specified. In conversations

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1. Holland, Op. cit., pp. 81-82.
 2. This parameter is composed of two parts for ease of coding.
 3. Holland, Op. cit., p. 82.
 4. $NCOR_1$ represents the initial value of the capital to output ratio and is discussed in the following section.

with members of the Center for International Studies India Project a set of initial capital to output ratios were arrived at. However, this set of values were in terms of the "value added" concept of output and required adjustment to correspond to definitions used in this model.¹ The value added concept may be expressed as follows:

$$5.30) \quad \text{NCOR1}^{\text{v.a.}} = \frac{(\text{KB1})(\text{PK1})}{(\text{QB1}) \left[(\text{P1}) - \sum_{i=2,3,5} (\text{Qi1})(\text{Pi}) \right]}$$

and when transposed to conform to our terminology becomes:

$$5.31) \quad \text{NCOR1} = \text{PK1}/\text{P1} = \text{NCOR1}^{\text{v.a.}} \left[1 - \sum_{i=2,3,5} (\text{Qi1})(\text{Pi})/\text{P1} \right]$$

Industrial Employment Index

Each of the industrial sectors utilizes labor both in production of the final good and in the capital creation process. That which goes into the production of the final good is $(\text{LPQAL})(\text{Q1})$ labor units per year.² That which goes into the capital creation process is $(\text{KGYR1})(\text{NCOR1})(\text{KL1})$ labor units per year. The total sectoral labor utilization, LBRL , then is the sum of the above:

$$5.32) \quad \text{LBRL} = (\text{LPQAL})(\text{Q1}) + (\text{KGYR1})(\text{NCOR1})(\text{KL1}) \quad \text{Labor units/yr.}$$

Where $\text{KGYR1} = \text{KGI}/\text{G1}$ plants per year and denotes the rate at which plants are being constructed.

1. See George Rosen, Industrial Change in India, Free Press, Glencoe, Ill., 1958, Chapter 3.

2. LPQAL , the average labor to output ratio, was derived in footnote 2, p. 75, above.

To derive the "Industrial Employment Index," LBRT, labor utilizations are summed for sectors 1, 3, 4, and 5 and divided by the initial value of the sum, so the index has a base of 1.

B. CAPITAL AND INTERMEDIATE GOODS (SECTOR 3)

This sector represents the large-scale capital and intermediate goods manufacturing sector of the economy plus the supply of equivalent imported goods. In order of importance some of the industries included in the sector are: mining (including coal), iron and steel, engineering, nonferrous metals, cement and other building materials. Initially over seventy-five per cent of domestic output is produced by these five industries. Analytically the structure of the sector is quite similar to that described above for sector 1. However, the structural parameters and input-output coefficients are quite different. Rather than duplicating the discussion pertaining to sector 1, only differences in structure between the two sectors will be discussed here.¹

The short-run supply function in this sector is the aggregate of both domestically produced and imported capital and intermediate goods. The imported product is assumed to be a perfect substitute for the domestic product. The domestic portion of the supply function is similar to that discussed in Part A. Intermediate goods used in

1. This approach will also hold in the discussion of the Public Overhead Capital Sector in the following section.

the production process, however, are drawn from different sources such that the term accounting for intermediate goods costs becomes:

$$5.33) \quad \sum_{i=5,7} (P_i)(Q_{i3}) \quad \text{Billion Rs./Quant}$$

and total variable costs PA_3 for the marginal plant becomes:

$$5.34) \quad PA_3 = \sum_{i=5,7} (P_i)(Q_{i3}) + (W_3)(LP_{QQ3}) \quad \text{Billion Rs./Quant}$$

Where $P_3 = PA_3$ for $Q_{H3} \leq Q_{B3}$

The additional increment to the pricing equation (PEX_3) for outputs which exceed nominal capacity is not damped as was the case in sector 1 such that:¹

$$5.35) \quad PEX_3 = \left[(PA_3)(J_3)/Q_{B3} \right] (Q_{H3} - Q_{B3})$$

and the complete pricing equation for domestic output becomes:

$$5.36) \quad PH_3 = PA_3 + PEX_3 \quad \text{Billion Rs./Quant}$$

Where $PEX_3 = 0$ for $Q_{H3} \leq Q_{B3}$

The combined supply function of domestic and imported capital and intermediate goods consists of whatever portion of the domestic supply function lies below P_7 the import price (gross, including tariff), plus a completely elastic supply at that price. Conceivably, the import price could be below the whole domestic supply curve, or it could intersect the

1. Instead, the damping takes place in the price equalizing equation to be discussed below.

latter at a quantity less than capacity. Under these conditions capital [and intermediate] goods might be imported while all or some of domestic capacity stood idle. Only when the gross import price is above the domestic price [PH3] for capacity output will domestic capacity be fully utilized¹

To implement the above, a price equalization equation is established where any difference that may exist between the foreign and the domestic price causes demand to shift, through an exponential lag, from the source with the higher price to that with the lower until prices are again equal. Imports are denoted as Q7K and are simply the difference between total demand Q3 and that portion which is supplied domestically QH3:

$$5.37) \quad Q7K = Q3 - QH3 \quad \text{Quants/yr.}$$

for $Q7K > 0$

The price equalizing equation operating through QH3 is:

$$5.38) \quad QH3 = \int_0^t (QDOT3)(P7 - PH3) dt + QH3_{(t=0)} \quad \text{Quants/yr.}$$

for $QH3 > 0$

To allow for the price inequality that may exist because the adjustment is not instantaneous, a weighted price index is used for the combined supply of capital and intermediate goods:

1. Holland, Op. cit., p. 85.

$$5.39) P3 = \frac{[(Q7K)(P7) + (QH3)(PH3)]}{(Q3)} \quad \text{Billion Rs./Quant}$$

Total demand (Q3) for capital and intermediate goods comes both from their use in the capital creation process of sectors 1, 3, 4, and 5 and from their use as intermediate goods in production of the current output of sectors 1, 2, 4, and 5. In the capital creation process of the different sectors,

. . . it is assumed that capital [and intermediate] goods are needed in a fixed ratio to gross capacity construction and that these goods are manufactured for each project at a uniform rate during its gestation period. (The ratios and the gestation periods differ among sectors.) Thus each requires a flow of capital [and intermediate goods] which at any moment is directly proportional to the level of capacity under construction.¹

The demand for capital and intermediate goods in the capital creation process is:

$$5.40) \sum_{i=1,3,4,5} (NCOR_i)(K3_i)(KGYR_i) \quad \text{Quants/yr.}$$

and the demand for intermediate goods in the final goods process of each of the using sectors is a function of the respective input-output coefficients such that total demand (Q3) becomes:

$$5.41) Q3 = \sum_{i=1,3,4,5} (NCOR_i)(K3_i)(KGYR_i) + \sum_{i=1,2,4,5} (Q3_i)(Q_i) \\ \text{Quants/yr.}$$

1. Ibid., p. 83.

In addition to Q7K, the portion of capital and intermediate goods imports that is equivalent to the domestic product, QH3, there is an intermediate good, Q7I, used in the final-good process of sector 3, which cannot be produced domestically either for lack of raw materials or for other technical reasons:

$$5.42) \quad Q7I = (Q73)(QH3) \quad \text{Quants/Quant}$$

It is assumed that the foreign price indexes for both Q7I and Q7K are numerically equal. Thus the total value of imports of capital and intermediate goods in domestic currency is:

$$5.43) \quad IMD7 = P7 [Q7K + Q7I] \quad \text{Billion Rs./yr.}$$

All other parts of this sector are identical to that described previously in Section A.

C. PUBLIC OVERHEAD SERVICES (SECTOR 5)

This sector represents the Public Overhead Sector of the economy. Due to its diversified nature and the necessity for its product in most other sectors of the economy a large share of total investment will usually be directed towards it. The more important types of industries included are: electricity, railways, communications, residential housing and flood control facilities. The basic difference between this sector and those previously described in this chapter is that capital formation is assumed to be completely controlled by the

government. As previously noted, only differences in structure between this sector and sector 1 will be discussed here.

The mix of the labor force used in this sector closely approximates the mix found in sector 3. Therefore the wage rate in the two sectors is considered to be identical. Intermediate goods input into the production process of the sector is confined to one good such that intermediate goods cost becomes:

$$5.44) \quad (P3)(Q35) \quad \text{Billion Rs./Quant}$$

and total variable cost for the marginal plant is:

$$5.45) \quad PA5 = (P3)(Q35) + (W3)(LPQQ5) \quad \text{Billion Rs./Quant}$$

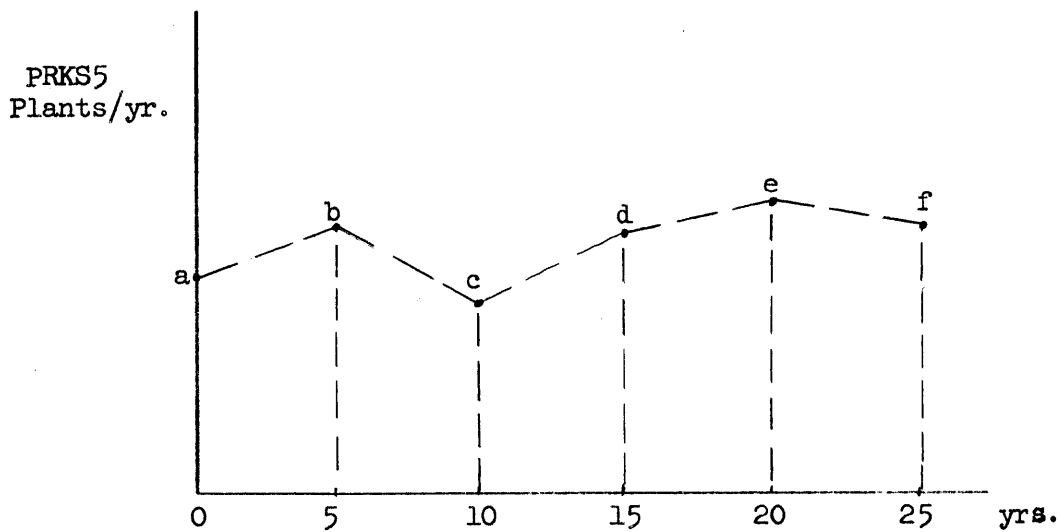
Creation of Public Overhead Capital is postulated as being completely under governmental control. Considering the nature of the sectors' output--and the Indian context--by far the major part of the sector is under public ownership with the privately owned segment coming under heavy governmental regulation. Two different methods have been used to determine PRKS5, the rate at which new capital projects are initiated.¹ In the 2000 series of runs a definite schedule was imposed. The schedule was specified by a series of points between which the DYNAMO program interpolated

1. Actually, the rate at which new projects are initiated is RKS5, which differs from PRKS5 in the event that ceiling controls are imposed. Normally, however, they are the same. (Ceiling controls are discussed in Chapter 8.)

linearly as indicated in the figure below. The corresponding DYNAMO equations are:¹

$$5.46) \text{ PRKS5} = \text{TABLE}(\text{RKS5T}, \text{TIME.K}, 0, 25, 5)$$

$$5.47) \text{ RKS5T}^* = a/b/c/d/e/f$$



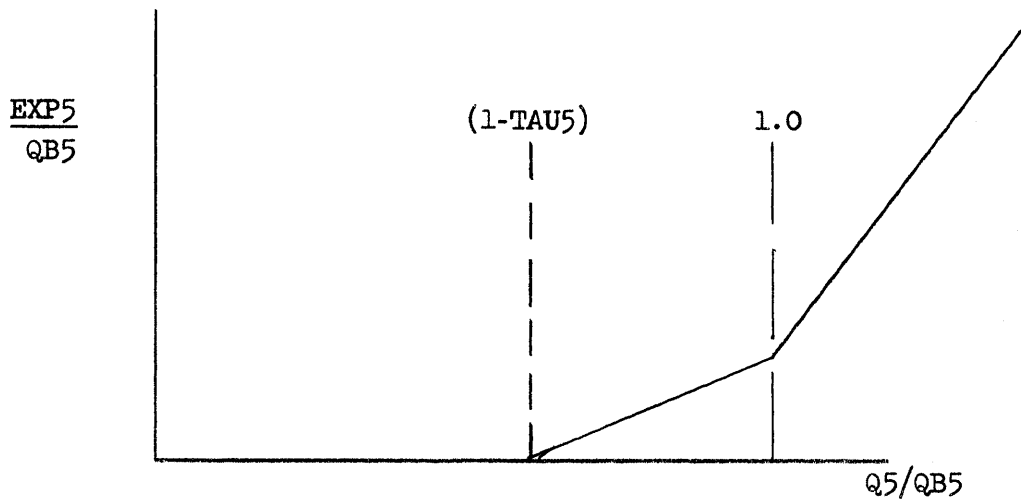
In the 3000 series of runs, capacity creation, instead of being preprogrammed, was initiated by a feedback signal related to the current supply and demand situation. This was designed to match the capacity of sector 5 roughly to the requirements of other sectors. The mechanism is similar to the investment decision function of sector 1, discussed above, except that the "target" increment of capacity, EXP5, is determined directly from the ratio of actual output to capacity instead of through a profitability variable. The function is:

1. See DYNAMO Memo D-47, Op. cit.

$$5.48) \quad PRK5 = RKR5 + LAMD5 \left[(EXP5) - (KG5) + (KE5) \right]$$

Plants/yr.

All of the other terms in this equation—RKR5, KG5, etc.—correspond to those in the sector 1 function except EXP5, the target increment of capacity. This target, as a proportion of existing capacity, is a simple but nonlinear function of capacity utilization, i.e. of the ratio of output to capacity, $Q5/QB5$, as shown graphically below:



The equations of this function are:

$$5.49) \quad EXP5 = (QB5) \left[(ADK5) (GAMA5) + (ADKW5) (GAMB5) \right]$$

Plants/yr.

$$5.50) \quad ADK5 = \begin{cases} 0 & \text{when } (Q5/QB5) < (1 - TAU5) \\ (Q5/QB5) - (1 - TAU5) & \text{when } (Q5/QB5) > (1 - TAU5) \end{cases}$$

$$5.51) \text{ ADKW5} = \begin{cases} 0 & \text{when } Q5/QB5 < 1 \\ (Q5/QB5 - 1) & \text{when } Q5/QB5 > 1 \end{cases}$$

Where TAU5, GAMA5, and GAMB5 are parameters.

Thus, below a certain threshold where $Q5 = (1 - \text{TAU5})(QB5)$, the variable EXP5 is zero and capacity creation is limited solely to replacement. Above that threshold level of utilization, creation of additional capacity is started in proportion to the degree by which utilization exceeds the threshold. If utilization exceeds nominal capacity, the proportionality factor is increased.

Demand for the product, Q5, comes both from consumers and from other producing sectors. Demand by consumers, as stated in Chapter 4, has unity price elasticity; thus in value terms it is independent of the price, P5 (although it is affected by the price of food, P2). Demand from other sectors is indirectly affected, as the price P5 affects the price of--and hence the sales of--their output. Total demand for this sector's output is:

$$5.52) \text{ Q5} = (\text{CV5}/\text{P5}) + \sum_{i=1,3,4} (Q_i)(Q_{5i}) \quad \text{Quants/yr.}$$

D. PARAMETER VALUES

This section deals with the background data used in establishing certain of the parameter values used in this chapter. A number of the parameters are of the type for which statistical information is unavailable. Values for these were chosen on the basis of the most plausible dynamic behavior of the variables affected. Prominent in this category are the speed-of-response coefficients and time constants such as $LAMD_i$, $OMEG_i$, $QDOT_3$, etc. Several other constants were kept at their neutral values such as $ALFA_i = 1$, $DELHI = 0$. A number of others such as $GRTH_i$, $NGAM_i$, J_i , etc., were the result of alignment to given initial conditions. The more important parameters about which statistical information is available are discussed below.

Capital to Output Ratios

Capital to output ratios for the various producing sectors of an economy have come in for considerable analysis by development specialists. Values of the aggregate C.O.R. for the Indian economy suggested by various economists range from 2 to $3\frac{1}{2}$ to 1. This is a relatively wide range for such an important planning parameter. P. C. Mahalanobis suggests a value of 0.5 for the income-coefficient of capital (i.e. a C.O.R. = 2.0) and aligns his sectoral values so as to aggregate to that value.¹ Colin Clark suggests that, ". . . India's coefficient will probably be rather low--say, 2.5--for some time, but will tend

1. P. C. Mahalanobis. "The Approach of Operational Research to Planning in India," Sankhya, Vol. 16, Parts 1 and 2, (December 1955), p. 31.

to rise; . . ."¹ Coale and Hoover have a rather extensive analysis of sectoral values and come to the conclusion that:

Despite the statistically favorable ratio of income growth to investment during the past few years, it remains to be seen whether the relationship in India over the next two or three decades will be much different from the customary 3 or $3\frac{1}{2}$ to 1.²

In consultation with Dr. George Rosen a set of values pertaining to the particular nature of the five producing sectors of this model were selected. These values are tabulated below on the basis of two different definitions. They are listed first on the value-added basis, which Dr. Rosen uses and which is more closely related to the value for the over-all economy. In the other column they are given on the gross-output basis, which was used as a matter of convenience in this model. (The nature of the conversion is given on page 86.)

CAPITAL-OUTPUT RATIOS

<u>Sector</u>	<u>Value-added Basis</u>	<u>Gross-output Basis</u>
1	4.0	2.70
2	1.5	1.50
3	5.0	3.90
4	1.5	1.30
5	7.0	6.65

1. Colin Clark, "From Wealth to Capital Coefficients," Eastern Economist, January 20 - February 24, 1956.

2. Coale & Hoover, Population Growth and Economic Development in Low-Income Countries, Princeton, N.J., Princeton University Press, 1958, p. 184.

Using the above, the resultant aggregate C.O.R. for a typical run (2039) for the zero to five-year period was slightly over 3.0, which falls towards the high end suggested by the various economists cited above.

Gestation Times

Until very recently there has been no statistical data on capital gestation periods. This lack has been partially overcome by a survey by the Indian Planning Commission.¹ In that survey, analysis of time lags in the course of completion of an investment program are broken down into five time periods. That period which is relevant to this model is the period from the initiation of major expenditures on a project to cessation of investment expenditures and realization of final installed capacity. Based on the discussion in the report, this was approximated by the time lag corresponding to their notation of (f,c), from the date of issue of an import license to the date of realization of final installed capacity. Data from Table T4 of that memorandum is shown below (translated into years).²

1. Investment-Output-Employment Relationships, Phasing of Investments and Time Lags in Organized Manufacturing Industry, Perspective Planning Division, Planning Commission (India), New Delhi, March 1960.

2. Ibid., p. 11

<u>Name of Product</u>	<u>Time Lag (yrs.)</u>
Sugar	2.3 - 5.0
Cotton Yarn	2.8 - 5.0
Paper	2.5 - 9.2
Cement	3.3 - 4.6

From a number of product category listings the following additional information was obtained.¹

<u>Name of Industry</u>	<u>Number of Final Products</u>	<u>Avg.</u>	<u>Time Lag (yrs.)</u>	
			<u>High</u>	<u>Low</u>
Metallurgical	14	3.2	4.7	0.5
Industrial Machinery	7	3.3	3.6	3.0
Electrical Equipment	6	3.0	4.7	2.2

Although the Gi values were selected prior to the availability of this information they are consistent with that data and are listed below.

<u>Sector</u>	<u>Gi</u>	<u>Ei</u>
1	3	1
3	4	1
5	4	2

Labor to Output Ratio

It has been postulated in the model that the reduction in the labor to output ratio of each new plant coming into production is a

1. Ibid., Tables 8 & 9, pp. 28-30 of Statistical Appendix.

function of technological progress which in turn is a function of capital creation. Relating this improvement to capital creation, although a justifiable assumption, presents the problem that all available statistical material expresses the improvement as a time trend. Output per man-hour in the United States is supposed to have increased at an annual rate of 2.2 per cent between 1899 and 1950.¹ The annual percentage rate of increase in efficiency for England, France and Germany is cited as 0.3, 1.1, and 1.5 respectively.² In general it would seem that the range $1\frac{1}{4}$ - $1\frac{1}{2}\%$ annually would be applicable to the Indian context.³ In order to achieve the $1\frac{1}{4}$ - $1\frac{1}{2}\%$ as an annual rate it was necessary to make an estimate of the expected total of plants completed in the modern-industrial sectors of the model. Given this estimate, values of the parameter MU_i for each sector were selected such that the productivity improvement in the industrial sectors would be approximately $1\frac{1}{4}$ - $1\frac{1}{2}\%$ per year. The respective MU_i 's were established as:

$$MU_1 = 0.010$$

$$MU_3 = 0.008$$

$$MU_5 = 0.008$$

The initial values for the LPQ_i 's were determined previously.⁴

1. C. M. Palvia, *Op. Cit.*, p. 36.

2. *Ibid.*, p. 35.

3. Palvia selects an annual rate of 1% for increase in knowledge only.

4. See Input-Output Table, Figure 5, p. 47.

The Wage Function

The wage rate for the industrialized sector of the Indian economy is in essence composed of three elements. They are a basic wage, a dearness allowance related to the consumers' price index, and a bonus related to profits of the enterprise.¹ The dearness allowance forms the major part of the total wage, sometimes being as much as 200% of the basic wage.² The bonus usually amounts to 10% of the workers' total annual earnings.³ The model as formulated relates the rate of increase of wages to profits, but not to the cost of living. The departure of this formulation from the actual situation is not as bad as might at first be thought, however, because in the model inflation is induced by high demand relative to capacity, which is also the necessary condition for high profits. Thus profits and inflation can be considered to be closely correlated. The intensity of the effect of profits on wages, WC_i , has been set at various values. Regarding the lags in this effect Kotler points out:

The lag between the auditing of the year's final profits and the award of bonus on that year's profits must be taken into consideration. . . . The auditing itself may not be completed until mid-year following the year in which the profits are made. If the bonus becomes a subject of dispute, [as is true in many cases] conciliation and adjudication proceedings will further postpone the fixation and award of bonus; the lag will be extended even more if the Lower Tribunal's award is appealed by one of the parties.⁴

1. See Philip Kotler, "Problems of Industrial Wage Policy in India," Ph.D. dissertation, M.I.T., August 1956, (unpublished).

2. Ibid., Table 15, p. 115.

3. Ibid., p. 343.

4. Ibid., p. 343.

Similar lags affect determination of the dearness allowance--a lag in obtaining official data and further lags due to the adjudications involved. The value for the WDi's used was selected as three years.

The Lifetime of Capital

No reference could be found regarding the lifetime of capital in the Indian context. The general shape of the decay function for capital used in the model is corroborated by Terborgh.¹ The average lifetimes, Di's, used in the model were suggested by Dr. Rosen and the Ai's were supplied by members of this project solely on an intuitive basis.

<u>Sector</u>	<u>Capital Lifetime (yrs.)</u>	
	<u>Di (Average)</u>	<u>Di - Ai (Minimum)</u>
1	40	15
3	40	25
5	40	15

1. George W. Terborgh, Realistic Depreciation Policy, M.A.P.I., Washington, 1954.

APPENDIX TO CHAPTER 5

DEFINITION OF VARIABLES IN SECTORS 1, 3, AND 5

- Note: The subscript (i) denotes that the variable appears in an identical form in more than one of the sectors.
- ADKA5 Intermediate variable used in determining ADK5.
- ADKW5 Intermediate variable used in determining EXP5.
- ADK5 Intermediate variable used in determining EXP5.
- CLCAi Generic name defining the moving train of memory storage cells used to store the values of $RKSi$ for the previous ($G_i - E_i$) years.
- CLCBi Generic name defining the moving train of memory storage cells used to store the values of $RKPi$ for the previous 7.5 years.
- CLCCi An extension to CLCBi.
- CLCD3 An extension to CLCC3.
- CLCE3 An extension to CLCD3.
- DELP3 The difference between the world price (P_7) and the home produced price (PH_3) of capital and intermediate goods (billions of rupees per quant).
- DRKSi The entrepreneurs' desired rate of starting new capital projects (plants per year).
- EXP5 Target increment of sector 5 capacity expansion (plants).
- GAMMi The relationship between the desired "target" increment to capacity and the expected return on investment (plants per unit of return per year).
- ICORi Incremental capital to output ratio (rupees of investment per rupee per year of output).

- INVi Money value of gross sectoral investment (billions of rupees per year).
- KBi Physical stock of capital (plants).
- KEi The number of plants which will expire in G_i years (plants).
- KGYRi Annual rate at which plants are being constructed (plants per year).
- KGi The total number of plant-projects in the "gestation" phase (plants).
- KPi The total number of new plants which have come into existence since time zero (plants).
- KWi Entrepreneurs' "wanted" increment of new plant construction (plants).
- LBRI Total sectoral usage of labor (labor units per year).
- LPQAi Labor to output ratio of the average producing plant (labor units per quant).
- LPQBi Intermediate variable used in determining LPQAi.
- LPQCi Intermediate variable used in determining LPQAi.
- LPQDi Intermediate variable used in determining LPQCi and LPQQi.
- LPQEi Intermediate variable used in determining LPQDi.
- LPQMi Labor to output ratio of the newest plant in active production (labor units per quant).
- LPQQi Labor to output ratio of the least efficient plant in active production (labor units per quant).
- PAi Total production costs for the marginal producing plant (billions of rupees per quant).
- PEXAi Intermediate variable used in determining PEXi.
- PEXi Increment to the price caused by production above "nominal" capacity (billions of rupees per quant).

- PIAVi Sectoral average net per unit profit rate (billions of rupees per quant).
- PIMAi Net per unit profit rate of the most efficient plant in active production in sector i (billions of rupees per quant).
- PH3 Price of domestically produced capital and intermediate goods (billions of rupees per quant).
- PKi Capital cost (billions of rupees per plant).
- PRKS5 Programmed rate of starting new capital projects (plants per year).
- PROFi Gross sectoral profit flow (billions of rupees per year).
- Pi Commodity price (billions of rupees per quant).
- QA3 Intermediate variable, that part of Q3 used in the final consumer goods process, used in determining Q3 (quants per year).
- QA5 Intermediate variable, that part of Q5 used as a final consumer good, used in determining Q5 (quants per year).
- QBi "Nominal" capacity output (quants per year).
- QCi Intermediate variable used in determining Qi.
- QD3 Intermediate variable used in determining QH3.
- QEXi Excess of current production above "nominal" capacity (quants per year).
- QH3 Domestic production of capital and intermediate goods (quants per year).
- QH3DT Intermediate variable used in determining QH3.
- Qi Sectoral output (quants per year).
- QPR5 Intermediate variable used in determining ADK5 and ADKW5.
- QPRA5 Intermediate variable used in determining QPR5.
- Q7 Total imports of capital and intermediate goods (quants per year).
- Q7K Total imports of those capital and intermediate goods which are perfect substitutes for the domestically produced product (quants per year).

- Q7KDT Intermediate variable, DT rate of Q7K, used in determining RQH3B (quants per year per DT).
- REOiT Intermediate variable, containing the time profile of RKEOi, used in determining RKEi (plants per year).
- RKDi Rate at which plants are expiring (plants per year).
- RKEi Intermediate variable used in determining RKDi.
- RKEOi Intermediate variable, that portion of RKEi which is attributable to plants constructed prior to time zero, used in determining RKEi.
- RKPAi Intermediate variable used in determining RKPi.
- RKPi Rate at which new plants are entering their production phase (plants per year).
- RKQi Intermediate variable used in determining RK Ri.
- RKQOi Intermediate variable, that portion of RKQi which is attributable to plants constructed prior to time zero, used in determining RKQi.
- RKRi Rate at which existing plants will expire G_i years in the future (plants per year).
- RPAOi Intermediate variable, that portion of RKPAi which is attributable to plant-projects started prior to time zero, used in determining RKPAi (plants per year).
- RPEAi Intermediate variable used in determining PEXi.
- RPEBi Intermediate variable used in determining PEXi.
- RPECi Intermediate variable used in determining PEXi.
- RPEXi Intermediate variable used in determining PEXi.
- RQH3A Intermediate variable, to limit Q7K to positive values only, used in determining QH3 (quants per year).
- RQH3B Intermediate variable, to limit QH3 to positive values only, used in determining QH3 (quants per year).
- RQH3C Intermediate variable, used in determining QH3.

- RQH3N Intermediate variable, the negative value of RQH3C, used in determining QH3.
- RQH3P Intermediate variable, the positive value of RQH3C, used in determining QH3.
- RQOiT Intermediate variable, containing the time profile of RKQOi, used in determining RKQi.
- RWai Intermediate variable, positive values only of RWBi, used in determining Wi (billions of rupees per labor unit per year).
- RWBi Intermediate variable, specifying the rate of change of average profit per labor unit used in determining Wi (billions of rupees per labor unit per year).
- RWi Intermediate variable, defined in the control sector.
- Wai Intermediate variable, positive values of WB3 only, used in determining Wi (billions of rupees per labor unit per year).
- WBi Intermediate variable, the rate of change of the wage rate, used in determining Wi (billions of rupees per labor unit per year).
- Wi Wage rate (billions of rupees per labor unit).
- XRi Expected rate of return on investment capital (rupees per year per rupee).
- ZETAi Intermediate variable, related to the magnitude of the PEKi term, used in determining Pi ((rupees/quant) per (quant/year)).

DEFINITIONS OF PARAMETERS IN SECTORS 1, 3, AND 5

- ALFAi Accuracy of individual entrepreneurs' allowances for others' projects, used in equation for KWi (dimensionless).
- Ai Time constant used in equations for RKRI and RKDi (years).
- CLCAi* Past history values of RKS_i, used in equation for CLCAi (plants per 0.25 years).

- CLCzi* (z = B, C, D, E) past history values of RKP_i (plants per 0.25 years).
- DELH_i Adjustment for optimism or pessimism in determining the expected rate of return on investment capital, used in equation for XRI (billions of rupees per year per billions of rupees).
- E_i Time constant, used in equation for RKP_i (years).
- GAMA₅ Proportionality constant used in determining the variable EXP₅.
- GAMB₅ Proportionality constant used in determining the variable EXP₅.
- GRTH_i Used in determination of the dynamic characteristic of the variable GAMM_i (years).
- G_i Average gestation time for all plant-projects in sector i (years).
- J_i Proportionality constant, used in equation for ZETA_i (dimensionless).
- LAMD_i Speed-of-response coefficient, used in equation for DRKS_i (proportion per year).
- LPQN_i Labor to output ratio of newest active plant at time zero (labor units per quant).
- MD_i Time constant, defining intersector mobility lag, used in equation for W_i (years).
- MU_i Relationship between capital creation and decreases in the labor to output ratio, used in equations for LPQ_{Di}, LPQE_i (proportion per plant).
- NCOR_i Initial value of the capital to output ratio (rupees of investment per rupee per year of output).
- NGAM_i Parameter, used in equation for GAMM_i (plants per unit of return per year).
- OH_i Overhead per unit investment (rupees per year per rupee of capital).
- OMEG_i Time constant, used in equation for the rate of change of PEX_i (years).
- QDJT₃ Speed-of-response coefficient, used in equation for QH₃.

- TAU5 Parameter, used in determining EXP5 (dimensionless).
- WCI Proportionality parameter, used in equation for W_i (dimensionless).
- WDi Time constant, defining lag in response of wage rate to profit rate, used in equation for W_i (years).

SECTOR 1 EQUATIONS

PROFIT AND INVESTMENT

20A	$LPQQ1.K = LPQN1 / LPQD1.K$	EH1001
14A	$LPQE1.K = 1 + (MU1)(KP1.K)$	EH1002
14A	$LPQD1.K = LPQE1.K + (-MU1)(Q1.K)$	EH1003
20A	$LPQC1.K = LPQD1.K / LPQE1.K$	EH1004
42A	$LPQB1.K = LPQN1 / ((MU1)(Q1.K))$	EH1005
29A	$LPQA1.K = (-LPQB1.K) LOGN(LPQC1.K)$	EH1006
20A	$LPQM1.K = LPQN1 / LPQE1.K$	EH1007
16A	$PIAV1.K = (W1.K)(LPQQ1.K) + (1.00)(PEX1.K) + (W1.K)(-LPQA1.K) + (-OH1)(PK1.K)$	EH1008
16A	$PIMA1.K = (W1.K)(LPQQ1.K) + (1.00)(PEX1.K) + (-W1.K)(LPQM1.K) + (-OH1)(PK1.K)$	EH1009
17A	$PROF1.K = (PIAV1.K)(Q1.K)(1) + (Q1.K)(OH1)(PK1.K) + (0)(0)(0)$	EH1010
12A	$INV1.K = (PK1.K)(KGYR1.K)$	EH1011
20A	$KGYR1.K = KG1.K / G1$	EH1012

INITIAL CONDITIONS AND CONSTANTS

C	$LPQN1 = .2410 / MU1 = 0.010 / OH1 = 0.11$	EH1013
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INVESTMENT DECISION FUNCTION

15A	$DRKS1.K = (RKR1.JK)(1) + (KW1.K)(LAMD1)$	EH1050
27A	$XR1.K = (PIMA1.K / PK1.K) + DELH1$	EH1051
16A	$KW1.K = (XR1.K)(GAMM1.K) + (KG1.K)(-ALFA1) + (KE1.K)(1) + (1)(0)$	EH1052
14A	$GAMM1.K = NGAM1 + (GRTH1)(KB1.K)$	EH1053

INITIAL CONDITIONS AND CONSTANTS

C	$LAMD1 = 0.20 / NGAM1 = 73 / ALFA1 = 1 / DELH1 = 0 / GRTH1 = 0.00$	EH1054
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CAPITAL LIFE CYCLE

1L	$KG1.K = KG1.J + (DT)(RKS1.JK - RKP1.JK)$	EH1100
1L	$KE1.K = KE1.J + (DT)(RKR1.JK - RKD1.JK)$	EH1101

14A RE01T.K=0.24+(.0190)(TIME.K) EH1130

INITIAL CONDITIONS AND CONSTANTS

6N KG1=1.50 EH1132

C G1=3/A1=25/E1=1 EH1131

PRICE AND WAGE FORMATION

16A PA1.K=(P3.JK)(Q31)+(P2.JK)(Q21)+(P5.JK)(Q51)+(W1.K)(LPQ01.K) EH1148

7R P1.KL=PA1.K+PEX1.K EH1149

44A ZETA1.K=(PA1.K)(J1)/QB1.K EH1150

3L W1.K=W1.J+(DT)(1/WD1)(RW1.J+0) EH1151

NOTE RW1 DEFINED IN APPENDIX TO CHAPTER 9 CONTROL SECTOR

51A WA1.K=CLIP(WB1.K,0,WB1.K,0) EH1152

22A WB1.K=(1/MD1)((WD1)(W3.K)+(-WD1)(W1.K)) EH1153

51A RWA1.K=CLIP(RWB1.K,0,RWB1.K,0) EH1154

44A RWB1.K=(WC1)(PIAV1.K)/LPQA1.K EH1155

1L PEX1.K=PEX1.J+(DT)(RPEX1.JK+0) EH1156

51R RPEX1.KL=CLIP(RPEA1.K,RPEC1.K,RPEB1.K,0) EH1157

21A RPEA1.K=(1/OMEG1)(PEXA1.K-PEX1.K) EH1158

15A RPEB1.K=(PEX1.K)(1)+(DT)(RPEA1.K) EH1159

20A RPEC1.K=-PEX1.K/DT EH1160

12A PEXA1.K=(ZETA1.K)(QEX1.K) EH1161

7A QEX1.K=Q1.K-QB1.K EH1162

6A QB1.K=KB1.K EH1163

17A PK1.K=(NCOR1)(K31)(P3.JK)+(NCOR1)(KL1)(W1.K)+(1)(0)(0) EH1164

INITIAL CONDITIONS AND CONSTANTS

6N P1=1.0 EH1165

6N W1=1.0 EH1166

6N PEX1=0.310 EH1167

C K31=0.7/KL1=0.3/J1=2.560/OMEG1=.5/Q31=.21/Q21=.10/Q51=.10/WD1=3 EH1168

C NCOR1=2.7 EH1169

C MD1=2 EH1170

C WC1=0.50 EH1171

QUANTITY DEMANDED

20A $QC1.K = C1.K / P1.JK$ EH1200
15A $Q1.K = (QC1.K)(1) + (QEX8.K)(Q18)$ EH1201

INCREMENTAL CAPITAL TO OUTPUT RATIO

20S $ICOP1.K = PK1.K / P1.JK$ EH1900

LABOR USEAGE

17S $LBR1.K = (KGYR1.K)(NCOR1)(KL1) + (LPGA1.K)(Q1.K)(1) + (0)(0)(0)$ EH1901

SECTOR 3 EQUATIONS

PROFIT AND INVESTMENT

20A	$LPQO3.K = LPQN3 / LPQD3.K$	EH3001
14A	$LPQE3.K = 1 + (MU3) (KP3.K)$	EH3002
14A	$LPQD3.K = LPQE3.K + (-MU3) (QH3.K)$	EH3003
20A	$LPQC3.K = LPQD3.K / LPQE3.K$	EH3004
42A	$LPQB3.K = LPQN3 / ((MU3) (QH3.K))$	EH3005
29A	$LPQA3.K = (-LPQB3.K) LOGN(LPQC3.K)$	EH3006
20A	$LPQM3.K = LPQN3 / LPQE3.K$	EH3007
16A	$PIAV3.K = (W3.K) (LPQO3.K) + (1.00) (PEX3.K) + (-W3.K) (LPQA3.K) + (-OH3) (PK3$	EH3008
X1	$.K)$	EH3008
16A	$PIMA3.K = (W3.K) (LPQO3.K) + (1.00) (PEX3.K) + (-W3.K) (LPQM3.K) + (-OH3) (PK3$	EH3009
X1	$.K)$	EH3009
17A	$PROF3.K = (PIAV3.K) (QH3.K) (1) + (QH3.K) (OH3) (PK3.K) + (0) (0) (0)$	EH3010
12A	$INV3.K = (PK3.K) (KGYR3.K)$	EH3011
20A	$KGYR3.K = KG3.K / G3$	EH3012

INITIAL CONDITIONS AND CONSTANTS

C	$OH3 = .08 / LPQN3 = .3640 / MU3 = .008$	EH3013
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INVESTMENT DECISION FUNCTION

15A	$DRKS3.K = (RKR3.JK) (1) + (KW3.K) (LAM3)$	EH3050
27A	$XR3.K = (PIMA3.K / PK3.K) + DELH3$	EH3051
16A	$KW3.K = (XR3.K) (GAMM3.K) + (KG3.K) (-ALFA3) + (KE3.K) (1) + (1) (0)$	EH3052
14A	$GAMM3.K = NGAM3 + (GRTH3) (KB3.K)$	EH3053

INITIAL CONDITIONS AND CONSTANTS

C	$LAM3 = .2 / NGAM3 = 465 / ALFA3 = 1.0 / DELH3 = 0 / GRTH3 = 0$	EH3054
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CAPITAL LIFE CYCLE

1L	$KG3.K = KG3.J + (DT) (RKS3.JK - RKP3.JK)$	EH3100
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PAST HISTORY OF CAPITAL LIFE CYCLE

51A	RPA03.K=CLIP(RA03T.K,0,3,TIME.K)	EH3131
14A	RA03T.K=0.25+(0.122)(TIME.K)	EH3132
51A	RKQ03.K=CLIP(RQ03T.K,0,21,TIME.K)	EH3133
14A	RQ03T.K=0.141+(0.00520)(TIME.K)	EH3134
51A	RKE03.K=CLIP(RE03T.K,0,25,TIME.K)	EH3135
14A	RE03T.K=0.12+(0.00520)(TIME.K)	EH3136

INITIAL CONDITIONS AND CONSTANTS

6N	KG3=1.55	EH3138
C	G3=4/A3=15/E3=1	EH3137

PRICE AND WAGE FORMATION

16A	PA3.K=(P7.JK)(Q73)+(P5.JK)(Q53)+(W3.K)(LPQ03.K)+(1)(0)	EH3148
7R	PH3.KL=PA3.K+PEX3.K	EH3149
3L	W3.K=W3.J+(DT)(1/WD3)(RW3.J+0)	EH3151
NOTE	RW3 DEFINED IN APPENDIX TO CHAPTER 9 CONTROL SECTOR	
51A	WA3.K=CLIP(WB3.K,0,WB3.K,0)	EH3152
22A	WB3.K=(1/MD3)((WD3)(W1.K)+(-WD3)(W3.K))	EH3153
51A	RWA3.K=CLIP(RWB3.K,0,RWB3.K,0)	EH3154
44A	RWB3.K=(WC3)(PIAV3.K)/LPQA3.K	EH3155
51A	PEX3.K=CLIP(PEXA3.K,0,PEXA3.K,0)	EH3156
46A	PEXA3.K=(PA3.K)(J3)(QEX3.K)/((QB3.K)(1)(1))	EH3157
7A	QEX3.K=QH3.K-QB3.K	EH3162
6A	QB3.K=KB3.K	EH3163
17A	PK3.K=(NCOR3)(K33)(P3.JK)+(NCOR3)(KL3)(W3.K)+(1)(0)(0)	EH3164
22R	P3.KL=(1/Q3.K)((Q7K.K)(P7.JK)+(QH3.K)(PH3.JK))	EH3165
7A	DELP3.K=P7.JK-PH3.JK	EH3166

INITIAL CONDITIONS AND CONSTANTS

6N	PH3=1.0	EH3167
6N	W3=1.0	EH3168
6N	P3=1.0	EH3169
C	K33=.70/KL3=.30/J3=1.380/Q73=.20/Q53=.10/WD3=3/MD3=2	EH3171
C	NCOR3=3.9	EH3172
C	WC3=0.5	EH3173

QUANTITY DEMANDED

8A	$Q3.K = QA3.K + QC3.K + QD3.K$	EH3197
16A	$QA3.K = (Q31)(Q1.K) + (Q32)(QH2.K) + (Q34)(Q4.K) + (Q35)(Q5.JK)$	EH3198
17A	$QC3.K = (NCOR1)(K31)(KGYR1.K) + (NCOR3)(K33)(KGYR3.K) + (NCOR4)(K34)(KGY$	EH3199
X1	$R4.K)$	EH3199
17A	$QD3.K = (NCOR5)(K35)(KGYR5.K) + (1)(0)(0) + (1)(0)(0)$	EH3200
7A	$Q7K.K = Q3.K - QH3.K$	EH3201
15A	$Q7.K = (1)(Q7K.K) + (Q73)(QH3.K)$	EH3202
1L	$QH3.K = QH3.J + (DT)(RQH3A.J + RQH3B.J)$	EH3203
51A	$RQH3A.K = CLIP(Q7KDT.K, RQH3P.K, RQH3P.K, Q7KDT.K)$ KEEPS Q7K POSITIVE	EH3204
51A	$RQH3B.K = CLIP(QH3DT.K, RQH3N.K, QH3DT.K, RQH3N.K)$ KEEPS QH3 POSITIVE	EH3205
20A	$Q7KDT.K = Q7K.K / DT$	EH3206
20A	$QH3DT.K = -QH3.K / DT$	EH3207
51A	$RQH3P.K = CLIP(RQH3C.K, 0, RQH3C.K, 0)$ POSITIVE VALUES ONLY OF RQH3C	EH3208
51A	$RQH3N.K = CLIP(0, RQH3C.K, RQH3C.K, 0)$ NEGATIVE VALUES ONLY OF RQH3C	EH3209
12A	$RQH3C.K = (QDOT3)(DELPH3.K)$	EH3210

INITIAL CONDITIONS AND CONSTANTS

6N	$QH3 = 8.49$	EH3211
C	$QDOT3 = 20.0$	EH3212

INCREMENTAL CAPITAL TO OUTPUT RATIO

20S	$ICOR3.K = PK3.K / PH3.JK$	EH3900
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LABOR USAGE

17S	$LBR3.K = (KGYR3.K)(NCOR3)(KL3) + (LPQA3.K)(QH3.K)(1) + (0)(0)(0)$	EH3901
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SECTOR 5 EQUATIONS

PROFIT AND INVESTMENT

20A $LPQQ5.K = LPQN5 / LPQD5.K$ EH5001
 14A $LPQE5.K = 1 + (MU5)(KP5.K)$ EH5002
 14A $LPQD5.K = LPQE5.K + (-MU5)(Q5.K)$ EH5003
 20A $LPQC5.K = LPQD5.K / LPQE5.K$ EH5004
 42A $LPQB5.K = LPQN5 / ((MU5)(Q5.K))$ EH5005
 29A $LPQA5.K = (-LPQB5.K) \text{LOGN}(LPQC5.K)$ EH5006
 17A $PROF5.K = (Q5.K)(W3.K)(LPQQ5.K) + (Q5.K)(1.00)(PEX5.K) + (Q5.K)(W3.K)(-L$ EH5007
 X1 $PQA5.K)$ EH5007
 20A $KGYR5.K = KG5.K / G5$ EH5008
 44A $INV5.K = (KG5.K)(PK5.K) / G5$ EH5009

INITIAL CONDITIONS AND CONSTANTS

C $LPQN5 = 0.3121 / MU5 = 0.008 / G5 = 4$ EH5010

INVESTMENT DECISION FUNCTION

2000 SERIES

59R $PRKS5.KL = \text{TABLE}(RKS5T, 0, 25, 5)$ EH5050
 C $RKS5T* = A/B/C/D/E/F$ SPECIFIED IN PROGRAM EH5051

3000 SERIES

7A $QPR5.K = QPRA5.K + \text{TAU5}$ EH5050
 27A $QPRA5.K = (Q5.K / QB5.K) - 1$ EH5051
 51A $ADK5.K = \text{CLIP}(ADKA5.K, 0, QPR5.K, 0)$ EH5052
 20A $ADKA5.K = QPR5.K / \text{TAU5}$ EH5053
 51A $ADKW5.K = \text{CLIP}(QPRA5.K, 0, QPR5.K, \text{TAU5})$ EH5054
 17A $EXP5.K = (QB5.K)(ADK5.K)(GAMA5) + (QB5.K)(ADKW5.K)(GAMB5) + (0)(0)(0)$ EH5055
 8A $KW5.K = EXP5.K - KG5.K + KE5.K$ EH5056
 15A $PRKS5.K = (RKR5.JK)(1) + (\text{LAM}D5)(KW5.K)$ EH5057

INITIAL CONDITIONS AND CONSTANTS

C $GAMA5 = 0.10 / GAMB5 = 0.3 / \text{LAM}D5 = .5 / \text{TAU5} = 0.1$ EH5059

51A	RK005.K=CLIP(RQ05T.K,0,11,TIME.K)	EH5133
14A	RQ05T.K=0.211+(.0227)(TIME.K)	EH5134
51A	RKE05.K=CLIP(RE05T.K,0,15,TIME.K)	EH5135
14A	RE05T.K=0.12+(.02270)(TIME.K)	EH5136

INITIAL CONDITIONS AND CONSTANTS

6N	KG5=3.02	EH5138
C	A5=25/E5=2	EH5137

PRICE FORMATION

44A	ZETA5.K=(PA5.K)(J5)/QB5.K	EH5148
15A	PA5.K=(W3.K)(LPQ05.K)+(P3.JK)(Q35)	EH5149
7R	P5.KL=PA5.K+PEX5.K	EH5150
1L	PEX5.K=PEX5.J+(DT)(RPEX5.JK+0)	EH5151
51R	RPEX5.KL=CLIP(RPEA5.K,RPEC5.K,RPEB5.K,0)	EH5152
21A	RPEA5.K=(1/OMEG5)(PEXA5.K-PEX5.K)	EH5153
15A	RPEB5.K=(PEX5.K)(1)+(DT)(RPEA5.K)	EH5154
20A	RPEC5.K=-PEX5.K/DT	EH5155
12A	PEXA5.K=(ZETA5.K)(QEX5.K)	EH5156
7A	QEX5.K=Q5.JK-QB5.K	EH5157
6A	QB5.K=KB5.K	EH5158
17A	PK5.K=(NCOR5)(K35)(P3.JK)+(NCOR5)(KL5)(W3.K)+(1)(0)(0)	EH5225

INITIAL CONDITIONS AND CONSTANTS

6N	PEX5=0.61	EH5159
6N	P5=1.0	EH5160
C	Q35=.050/OMEG5=.500/J5=4.184	EH5161
C	K35=.800/KL5=.20	EH5227
C	NCOR5=6.65	EH5228

QUANTITY DEMANDED

20A	QA5.K=C5.K/P5.JK	EH5199
16R	Q5.KL=(Q1.K)(Q51)+(Q4.K)(Q54)+(QH3.K)(Q53)+(QA5.K)(1)	EH5200

6N	INITIAL CONDITIONS AND CONSTANTS Q5=10.11	EH5226
	INCREMENTAL CAPITAL TO OUTPUT RATIO	
20S	ICOR5.K=PK5.K/P5.JK	EH5900
	LABOR USAGE	
17S	LBR5.K=(KGYR5.K)(NCOR5)(KL5)+(LPQA5.K)(Q5.JK)(1)+(0)(0)(0)	EH5901

CHAPTER 6

AGRICULTURE AND NONPOWERED CONSUMER GOODS PRODUCTION

A. AGRICULTURE (SECTOR 2)

The agricultural sector is the largest producing sector of the economy. The major portion of its output is food crops. Also included in the output mix are products of the animal husbandry, fishery, and forestry industries. The relative importance of the sector cannot be expected to decline appreciably even in the course of a twenty-five year development program. A sufficient portion of developmental investment must be channeled into agriculture not only to meet the needs of a rapidly expanding population but also to replace the importation of food so as to ease the foreign exchange problem. At the same time, agricultural products are used as an intermediate input into several of the other sectors, and insufficient expansion of agricultural capacity, reflected in increasing prices of these inputs, could have adverse effects on the development of those sectors. Initially, agricultural output accounts for more than 50 per cent of the total domestic product, and more than 60 per cent of consumers' disposable income is directed towards food expenditure.

In most underdeveloped countries, a major part of agricultural production is consumed on the farm or in the village without any market transaction. This model, however, is set up as if all of the product were marketed and some then bought back for farm consumption. The consequences of this assumption are the same as if farmers kept part of the crop for home consumption, but only after considering the alternative purchases foregone and choosing the food as a matter of preference. This is not absolutely realistic, but is thought to be adequately so. Therefore "agricultural output" always refers to the total of the marketed and home-consumed product.¹

Short Run Supply

Farm labor is redundant and, being largely made up of proprietors and their dependent relatives, cannot be laid off. They do not receive fixed wages, but share the proceeds. Under these conditions, there are no significant variable costs that could be avoided by deciding not to produce, and therefore output always equals capacity, regardless of expected price. Changes in relative prices between different crops presumably affect farmers' decisions of what particular crop to plant next time, but it is assumed that these decisions do not affect the aggregate output; hence they do not need to be accounted for. Furthermore there is no inventory reaction to price changes. Inventory changes are not explicitly considered at all and are implied only in the distribution process and in smoothing the crop cycle into a steady flow to consumers.²

Given that domestic output, Q_H2 , is always equal to capacity, $KB2$, the pricing equation is reduced to the simple form of:

$$6.01) \quad P_2 = CT_2/Q_2 \quad \text{Billion Rs./Quant}$$

The numerator of the above constitutes the total demand for agricultural products (in value terms). This is the sum of export demand, intermediate good demand and final good demand for agricultural products, which are shown respectively below:

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1. Holland, *Op. cit.*, p. 55.
 2. *Ibid.*, pp. 55-56.

$$6.02) \quad CT_2 = (P_2)(Q_28)(Q_{EX8}) + \sum_{i=1,4} (P_2)(Q_{2i})(Q_i) + C_2$$

Billion Rs./yr.

The denominator of 6.01 above comprises the total supply of agricultural goods, both domestic, Q_{H2} , and imported, Q_{IM2} :

$$6.03) \quad Q_2 = Q_{H2} + Q_{IM2} \quad \text{Quants/yr.}$$

Capacity Changes

Agricultural production capacity is fixed by the area of land that has been cleared, the extent of irrigation facilities, and the production technique used. The physical establishment, or capital, is evaluated in terms of its capacity to produce with a particular standard technique. It does not really require identification separately from output capacity. However, since it is convenient to think of a fixed set of land and improvements in slightly different terms than a potential flow of output, it is given a separate symbol, $\sqrt{KB_2}$, and is measured in "land units"¹

Agricultural capital (or capacity) may be increased directly by such measures as land reclamation, irrigation projects, and improvement of seeds, or somewhat indirectly through community projects and the national extension service (i.e. by spreading new techniques). A majority of the above, either by virtue of finance--as in the case of the first two--or by virtue of coordination and assembly of the necessary experienced personnel--as in the case of the latter--must necessarily be accomplished through governmental supervision and control.

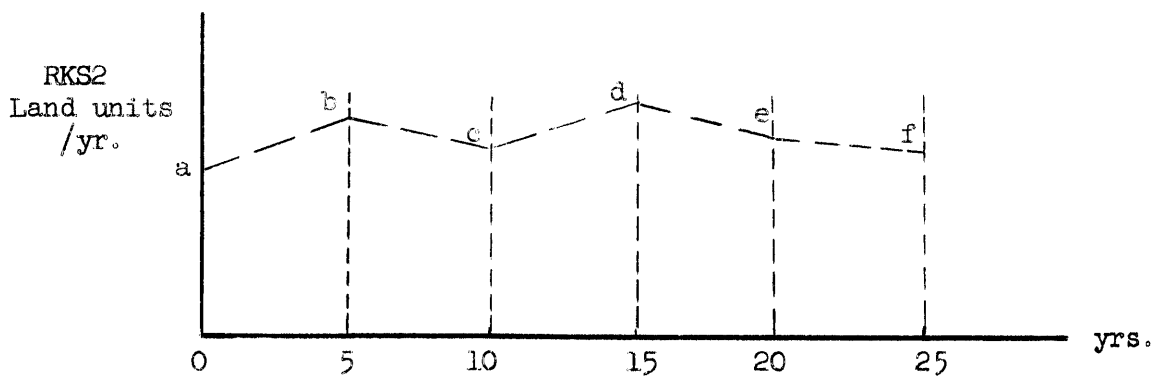
1. Ibid., p. 56.

Thus it is primarily government decisions that determine the extent of capacity-creating projects, although this does not mean that they are all carried out by the government. Some level of private capital formation would be carried out regardless of any government action and regardless of any of the economic variables in the model. In addition, some private capital formation will be undertaken as a result of government programs, which create opportunities to invest in land improvements, irrigation, and better tools. The assumption made here is that such private capital formation is in a fixed ratio to government capital formation.¹

Capital formation refers to both monetized and nonmonetized investment. The latter is assumed to be given an imputed value. The rate at which new capital projects are initiated, RKS2, is programmed for the model in the form of a definite schedule. The schedule is specified by a series of points between which the DYNAMO program interpolates linearly in the form shown below. (This is the same as one of the alternative methods used for sector 5 and described in Chapter 5, Section C.) The necessary DYNAMO equations are:²

$$6.04) \text{ RKS2} = \text{TABLE} (\text{RKS2T}, \text{TIME.K}, 0, 25, 5)$$

$$6.05) \text{ RKS2T*} = a/b/c/d/e/f$$



1. Ibid., p. 57.

2. See DYNAMO Memo D-47, Op. cit.

The analytic structure of the gestation period function is identical to that of other sectors, described in Chapter 5-A above.¹ Additions to capacity follow project starts after a combination of discrete delay and distributed lag with a combined average delay of G2 years. The number of land units in the gestation process at any time determines the gross rate of real capital formation, and the corresponding gross investment expenditure flow is related thereto through a variable capital cost index, PK2.

Capital cost in this sector is partly the cost of labor-intensive local projects, using rurally-made materials, and partly the cost of major modern construction, some parts of which, however, still use highly labor-intensive methods. Major irrigation works and multipurpose projects such as dams build capital for more than one sector. Arbitrarily they have been divided here between the public overhead and agriculture sectors, with the requirements for inputs from sector 3, the modern capital and intermediate goods sector, attributed to the public overhead portion. Thus the cost of capital for sector 2 is assumed made up largely of the cost of rural labor, with an additional component due to intermediate goods inputs from sector 4. Rural wages, on the basis of opportunity cost as well as cost of living, are assumed proportional to the price of food. Thus the sector 2 capital cost index has the form:

1. See pp. 77 to 79 for the gestation period equations which determine KP_i , KG_i , and INV_i for each sector.

$$6.06) \quad PK_2 = (NCOR_2) \int (KL_2)(P_2) + (K4_2)(P_4) \int$$

Billion Rs/land unit

Although the gestation phase for agricultural capacity is formulated identically with that of other sectors, the lifetime or attrition function is different. In this sector, (and in sector 4, described below,) attrition is assumed proportional to existing capacity:

$$6.07) \quad RKD_2 = (NU_2)(KB_2)$$

Land units/year

Thus, if gross investment were zero, capacity would decay exponentially toward zero. Combining this with the gross rate of additions to capital leads to the following equation for the capacity of the agricultural sector:

$$6.08) \quad KB_2 = KB_2(t=0) + \int_0^t \int [RKP_2 - (NU_2)(KB_2)] dt$$

Land units

B. NONPOWERED CONSUMER GOODS PRODUCTION (SECTOR 4)

The common denominator of the various activities included in sector 4--other than that little or no powered machinery is used--is the combination of low capital to output and high labor to output ratios. In terms of activities appropriate to India, the major categories included are: Village Industries, Handicrafts, Small-Scale Industries, Silk and Sericulture. Among village industries the more important ones are: cotton spinning and weaving, wool spinning and weaving, handpounding of rice, vegetable oils, tanning and leather,

and gur (a primitively processed form of sugar). The main justification for encouraging expansion of such village industries is the hope of lowering the proportion (as well as the absolute number) of the population dependent on agriculture for livelihood. It is stated that, "The most natural way of bringing this about is to provide as near to the village as possible means of nonagricultural productive employment."¹ Unlike the village industries and handicrafts, "small-scale" industries producing consumers goods are in general located in or near large cities rather than dispersed through the rural areas. (Small-scale industries producing capital and intermediate goods are considered to be part of sector 3.) They are somewhat larger than village industries and have a higher degree of organization. They form a somewhat heterogeneous grouping with their large variety and considerable differences in techniques and amount of capital employed. A workable definition of a fairly wide scope is that it includes all industries which have a capital investment of less than 500,000 rupees and employ less than 50 persons if they use power or less than 100 persons if they use no power. There is a tendency on the part of many economists to question the rationality of including a sector of the nature discussed above as part of a development model. Those who defend its promotion do so more on a social basis and in terms of the unemployment problem.

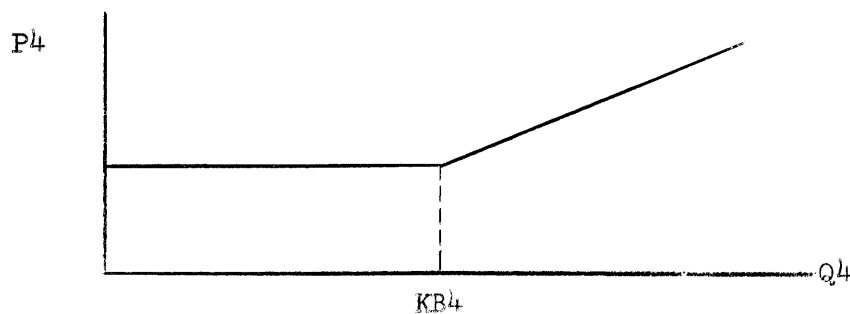
1. Report of the Village and Small Scale Industries (Second Five Year Plan) Committee, Government of India, Planning Commission, October 1955, p. 21.

One of the most important features of the existing economic situation is the large extent of unemployment and under-employment in the country. . . . It has been now fully accepted that in the next immediate phase of planned economic development in India the course of development should avoid as far as possible creation of technological unemployment. In terms of present numbers employed, this is largely the sphere of traditional hand and small scale industry. . . .¹

As in the agriculture sector, output and consumption of this sector's product also include the nonmarketed portion as if it were actually marketed.

Short Run Supply

Technology in most of the sector is "traditional" and therefore static in nature. Labor productivity is not only lower than in the modern industrial sectors but also does not tend to increase. Taking this into account, the short run supply curve is horizontal throughout the range up to "nominal" capacity. Above nominal capacity neither capital nor labor presents as stringent a bottleneck as in the modernized sectors. This being so the slope of the PEX₄ term is much less steep than those in sectors 1, 3, and 5. The figure below shows the short run curve which exhibits the above features.



1. Report of the Village and Small Scale Industries (Second Five Year Plan) Committee, Op. cit., pp. 14-15.

Since employment in most cases is in close proximity to agricultural lands, and since workers are unorganized, thus having farm life as an alternate opportunity, wages are closely correlated with agricultural prices. The minimum supply price prevailing at outputs below nominal capacity hence takes the form:

$$6.09) \quad PA^4 = (P_2)(Q_L^4) + \sum_{i=2,3,5} (P_i)(Q_i^4) \quad \text{Billion Rs./Quant}$$

The PEX^4 term is determined in the same manner as discussed in Chapter 5 above (pp. 72-74) and similarly the total supply price becomes:

$$6.10) \quad P^4 = PA^4 + PEX^4 \quad \text{Billion Rs./Quant}$$

Capacity Changes

As discussed in the preceding section, capacity in this labor-intensive sector is much more flexible than in agriculture, where output is limited by land and irrigation, or in the more mechanized sectors where machinery and equipment are presumed to be bottlenecks. Nevertheless, there is assumed to be a point in the short-run supply curve beyond which the price of output rises because of a scarcity of certain kinds of tools and equipment which are the capital of this sector. As in other sectors, this "capacity" can be increased by capital formation in excess of the rate of attrition.

Capital formation decisions in this sector are treated as government plan or policy decisions. As indicated by the quotations

earlier in this chapter promotion of this sector is a matter of government policy in India. The scope for private entrepreneurship, except as fostered by governmental subsidies or protection, is very much limited by the unprofitability of these forms of production relative to larger-scale and more modern industry. Thus even the private decisions are consequences of government decisions. Hence capital formation starts in the model are programmed in advance by exactly the same technique as described earlier for the agriculture sector.

The analytic structure of the gestation period, lifetime and attrition functions are identical to those discussed for Agriculture in Part A above. Only the parameter values differ.

Capital in this sector is created from capital goods, materials, and labor. The capital goods and materials come largely from this sector (sector 4), and to a smaller extent from the capital goods sector (sector 3). Most of the labor involved is comparable to that used for capital formation in agriculture and for current output of this nonpowered manufacturing sector. Hence, in this sector's capital formation, as in those activities, the labor input is evaluated at a rate proportional to the price of agricultural output. The cost of capital in sector 4, reflecting the three inputs, is thus:

$$6.10) \quad PK_4 = NCOR_4 \left[P_3(K_{34}) + P_4(K_{44}) + P_2(KL_4) \right]$$

Billion Rs./plant

C. PARAMETER VALUES

The background data for establishing several of the parameters used in this chapter will be discussed in this section. As was previously stated in Section D of Chapter 5 a number of the parameters used in this study are not covered in the available literature. Two parameters used in this chapter fall into this category. J_4 , the parameter determining the slope of the supply curve beyond nominal capacity, was the result of alignment of the sector to given initial conditions, $OMEG_4$, a speed of response coefficient, was chosen, like its counterparts in sectors 1, 3, and 5, to give plausible dynamic behavior to the pricing equation for demands which exceed capacity. The capital to output ratios for sectors 2 and 4 are discussed above in conjunction with those pertaining to the other producing sectors of the economy.¹

Gestation Times

Capital gestation time for small-scale industry was recently included as part of a study of the Delhi region, conducted by P. N. Dhar. It was discovered that out of the 320 units for which information was available 281 had started production the same year they had been founded. Drawing from this and other data presented he suggests that:

1. See pp. 96-97.

It can be safely concluded that in the industries surveyed here, the period of gestation, that is the time spent in planning the outlay and the actual period of construction, was not more than one year.¹

The gestation period in agriculture was estimated by Dr. Rosen as being the order of magnitude shown below.

<u>GESTATION TIMES</u>		
<u>Sector</u>	<u>Gi</u>	<u>Ei</u>
2	2	1.0
4	1	0.5

Attrition

Included in the Malenbaum figures cited previously were both gross and net investment figures for various sectors of the economy. Over a relevant five-year period depreciation in agriculture was on the average 35 per cent of total investment.² In order to approximate this with the function chosen, the resultant value of NU2 was 0.02. Depreciation in sector 4 industries was approximately the same and NU4 was assigned the same value.

1. P. N. Dhar, Small-Scale Industries in Delhi, Asia Publishing House, Delhi, 1958, pp. 15-16.

2. Malenbaum, Op. cit.

APPENDIX TO CHAPTER 6

DEFINITIONS OF VARIABLES IN SECTORS 2 AND 4

Note: Only those variables and parameters which were not previously defined in the Appendix to Chapter 5 (pp. 103-108) are included here.

- KBAi Auxiliary variable, the rate of change of real productive capacity, used in determining KBi (land units per year or plants per year).
- CTA2 Auxiliary variable, total demand for the agriculture product as an intermediate input, used in determining CT2 (billions of rupees per year).
- CT2 Total demand for agricultural products (billions of rupees per year).

DEFINITIONS OF PARAMETERS IN SECTORS 2 AND 4

- NUi Parameter establishing the rate of attrition as proportional to existing capacity (proportion per year).

SECTOR 2 EQUATIONS

INVESTMENT

44A $INV2.K = (KG2.K)(PK2.K)/G2$ EH2001
 20A $KG2.K = KG2.K/G2$ EH2002

INITIAL CONDITIONS AND CONSTANTS

C $G2 = 2$ EH2003

CAPITAL LIFE CYCLE

37B $CLC2 = BOXLIN(5, 0, 25)$ EH2010
 1L $CLC2*1.K = CLC2*1.J + (DT)(RKS2.JK + 0)$ EH2011
 20R $RKPA2.KL = CLC2*5.K/0.25$ EH2012
 39R $RKP2.KL = DELAY3(RKPA2.JK, E2)$ EH2013
 14A $KBA2.K = RKP2.JK + (-NU2)(KB2.K)$ EH2014
 1L $KB2.K = KB2.J + (DT)(KBA2.J + 0)$ EH2015
 1L $KG2.K = KG2.J + (DT)(RKS2.JK - RKP2.JK)$ EH2016

INITIAL CONDITIONS AND CONSTANTS

6N $KB2 = 61.78$ EH2017
 6N $KG2 = 3.66$ EH2018
 6N $RKPA2 = 1.83$ EH2019
 C $CLC2* = 0/.4575/.4575/.4575/.4575$ EH2020
 C $NU2 = .02/E2 = 1$ EH2022

PRICE FORMATION

17A $PK2.K = (NCOR2)(KL2)(P2.JK) + (NCOR2)(K42)(P4.JK) + (1)(0)(0)$ EH2030
 20R $P2.KL = CT2.K/Q2.K$ EH2031

INITIAL CONDITIONS AND CONSTANTS

6N $P2 = 1.0$ EH2032
 C $KL2 = .7/K42 = .3/NCOR2 = 1.5$ EH2033

QUANTITY DEMANDED

17A $CTA2.K = (P2.JK)(Q21)(Q1.K) + (P2.JK)(Q24)(Q4.K) + (P2.JK)(Q28)(QEX8.K)$ EH2040
7A $CT2.K = CTA2.K + C2.K$ EH2041
7A $Q2.K = QH2.K + QIM2.K$ EH2042
6A $QH2.K = KB2.K$ EH2043

INITIAL CONDITIONS AND CONSTANTS

C $Q32 = .015$ EH2044

INCREMENTAL CAPITAL TO OUTPUT RATIO

20S $ICOR2.K = PK2.K / P2.JK$ EH2400

SECTOR 4 EQUATIONS

PROFIT AND INVESTMENT

20A $KG4.K = KG4.K / G4$ EH4001
 44A $INV4.K = (KG4.K) (PK4.K) / G4$ EH4002
 19A $PROF4.K = (Q4.K) (P4.JK - PA4.K + 0 + 0)$ EH4003

INITIAL CONDITIONS AND CONSTANTS

C $G4 = 1.0 / E4 = 0.5$ EH4004

CAPITAL LIFE CYCLE

37B $CLC4 = BOXLIN(11, 0.25)$ EH4011
 1L $PEX4.K = PEX4.J + (DT) (RPEX4.JK + 0)$ EH4033
 1L $CLC4*1.K = CLC4*1.J + (DT) (RKS4.JK + 0)$ EH4012
 20R $RKPA4.KL = CLC4*3.K / .25$ $G4 = 1, E4 = 0.5$ EH4013
 39R $RKP4.KL = DELAY3(RKPA4.JK, E4)$ EH4014
 14A $KBA4.K = RKP4.JK + (-NU4) (KB4.K)$ EH4015
 1L $KB4.K = KB4.J + (DT) (KBA4.J + 0)$ EH4016
 1L $KG4.K = KG4.J + (DT) (RKS4.JK - RKP4.JK)$ EH4017

INITIAL CONDITIONS AND CONSTANTS

6N $KB4 = 7.9$ EH4018
 6N $KG4 = 0.17$ EH4019
 6N $RKPA4 = 0.17$ EH4020
 C $CLC4* = 0 / .0425 / .0425 / 0 / 0 / 0 / 0 / 0 / 0 / 0$ EH4021
 C $NU4 = 0.02$ EH4022

PRICE FORMATION

17A $PK4.K = (NCOR4) (K34) (P3.JK) + (NCOR4) (KL4) (P2.JK) + (NCOR4) (K44) (P4.JK)$ EH4029
 7R $P4.KL = PA4.K + PEX4.K$ EH4030
 16A $PA4.K = (QL4) (P2.JK) + (Q24) (P2.JK) + (Q34) (P3.JK) + (Q54) (P5.JK)$ EH4031
 44A $ZETA4.K = (PA4.K) (J4) / QB4.K$ EH4032

21A	$RPEA4.K = (1/OMEG4)(PEXA4.K - PEX4.K)$	EH4035
15A	$RPEB4.K = (PEX4.K)(1) + (DT)(RPEA4.K)$	EH4036
20A	$RPEC4.K = -PEX4.K/DT$	EH4037
12A	$PEXA4.K = (ZETA4.K)(QEX4.K)$	EH4038
7A	$QEX4.K = Q4.K - QB4.K$	EH4039
6A	$QB4.K = KB4.K$	EH4040

INITIAL CONDITIONS AND CONSTANTS

6N	$P4 = 1.0$	EH4043
6N	$PEX4 = 0.05$	EH4044
C	$QL4 = .787/K34 = .20/KL4 = 0.40/Q24 = 0.05/Q54 = .05/Q34 = .063/K44 = .4$	EH4041
C	$J4 = .4160/OMEG4 = 0.5/NCOR4 = 1.3$	EH4042

QUANTITY DEMANDED

7A	$Q4.K = QC4.K + QA4.K$	EH4200
20A	$QC4.K = C4.K/P4.JK$	EH4201
17A	$QA4.K = (NCOR4)(KGYR4.K)(K44) + (NCOR2)(KGYR2.K)(K42) + (1)(0)(0)$	EH4202

INCREMENTAL CAPITAL TO OUTPUT RATIO

20S	$ICOR4.K = PK4.K/P4.JK$	EH4900
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LABOR USEAGE

17S	$LBR4.K = (KGYR4.K)(NCOR4)(KL4) + (QL4)(Q4.K)(1) + (0)(0)(0)$	EH4901
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CHAPTER 7
FOREIGN SECTOR

This sector includes the supply of each kind of import, the demand for exports, and the equations necessary to define the balance of payments. In previous chapters exports and imports have been mentioned but not always in detail; in this chapter those that were only mentioned will be fully explained.

Import Supply

Three foreign prices are used in the model. Expressed in foreign currency, they are:

- PF6 - Price of imported consumer goods
- PF2 - Price of imported food
- PF7 - Price of imported capital and intermediate goods.

Initially these are set equal to $(\frac{1}{XR})$ so that in domestic currency they have an initial index of unity. We normally assume that foreign supply is perfectly elastic so that in foreign currency the prices will be constant. Different assumptions are perfectly possible, but were not tried in the first study which has been made with this model.

The domestic counterparts of these foreign prices, of course, reflect the effects of changes in exchange rates and tariffs.

Import Demand

Three different demands for imports arise in the model. They are:

1. For consumer goods, C_6 , by consumers.
2. For food, Q_{IM2} , by government to supplement domestic production.
3. For capital and intermediate goods, Q_7 , by the producing sectors.

The demand for C_6 is discussed in Chapter 4, under consumers' demand and need not be repeated.

The quantity of food imported is assumed to be completely controlled by government policy. Food imports are reduced in proportion to the growth of output of the agricultural sector. The foreign purchasing is done by the government but the imported food is sold domestically at the going market price. Any profits or losses are part of the government budget and are not explicitly identified. The equations for the above policy are:

$$7.01) \quad Q_{IM2} = NQ_{IM2} - (\text{THET2})(KB2 - NKB2) \geq 0$$

or:

$$d(Q_{IM2})/dt = - (\text{THET2})d(KB2)/dt$$

Where: Q_{IM2} = Quantity of food imported.
 NQ_{IM2} = Initial value of Q_{IM2} .
 THET2 = A parameter with value between zero and one which is set by government policy.
 $KB2$ = Capacity of the agricultural sector.
 $NKB2$ = Initial value of $KB2$.

The total imports of capital and intermediate goods are composed of two types of goods; the demand for each type being derived in a

different manner. One type, $Q7K$, is assumed to be a perfect substitute for $QH3$, the domestically produced equivalent. Thus the demand for $Q7K$ is a function of the difference between the price of the home products, $PH3$, and the price of the import in domestic currency $P7$, including tariff. Any difference between $P7$ and $PH3$ induces a shift in demand to the good with the lower price until the prices are again equal. The equations describing the equalizing process are included in the description of sector 3.

In addition to this price-induced portion, $Q7K$, the capital and intermediate goods imports include an intermediate good, $Q7I$, the demand for which is a fixed proportion, $Q73$, of the output of sector 3. It is assumed that for technical reasons, $Q7I$ cannot be produced domestically. We assume that the foreign prices of $Q7K$ and $Q7I$ are the same; therefore the total value of capital and intermediate goods imports in foreign currency is given by:

$$7.02) \quad IMF7 = PF7 [Q7K + (Q73)(QH3)]$$

Where $Q73$ is a technical coefficient.

Exports

Only one type of export exists in the model. This export good is composed in fixed proportions of sector 1 goods and sector 2 goods. The price is a weighted average of $P1$ and $P2$ using the same proportions as weights. Exports are not made directly from sector 2 because these products must receive some additional fabrication

before they are exportable; under the assumptions of the model sector 2 only produces the unprocessed agricultural product. It is assumed that the factors used to process the raw material are of the same type as used in sector 1. Thus the major part of the sector 2 component of the export good is raw materials, the part coming from sector 1 is value added for fabrication plus some other goods of sector 1 type.

The demand function is assumed to be of constant elasticity, $ELEX_8$. This assumption is made in order to have $ELEX_8$ a parameter rather than a variable depending upon price, and thus facilitate comparisons of the effects of elasticity on devaluation.

The equations are:

$$7.03) \quad QEX_8 = (CHI_8)(PF_8)^{ELEX_8}$$

$$7.04) \quad PF_8 = (1/XR)(P_8)$$

$$7.05) \quad P_8 = (Q1_8)(P1) + (Q2_8)(P2)$$

$$7.06) \quad EXF_8 = (PF_8)(QEX_8)$$

Where: QEX_8 = The quantity of exports demanded.
 PF_8 = The price of exports in foreign currency.
 P_8 = The price of exports in domestic currency.
 $Q1_8$ and $Q2_8$ = Parameters which define respectively the quantity of sector 1 produce and sector 2 product in one unit of the export good.
 CHI_8 = A parameter which is determined by the initial conditions and the value selected for $ELEX_8$.

Balance of Payments

The balance of payments in foreign currency is defined as:

$$7.07) \text{ BPF} = \text{EXF8} + \text{FCAP} - \text{IMF2} - \text{IMF6} - \text{IMF7}$$

Where: EXF8 = Value of exports in foreign currency.
 FCAP = Net inflow of long-term capital in foreign currency.
 IMF2 = Value of food imports in foreign currency.
 IMF6 = Value of consumer goods imports in foreign currency.
 IMF7 = Value of capital and intermediate goods imports in foreign currency.

All of the components of BPF, with the exception of FCAP, have been discussed elsewhere. FCAP is an exogenous function which is used to represent grants, long-term loans or private direct investment. Situations where an inflow of foreign capital directly results in an outflow at some point in time--e.g. interest payments-- are not treated explicitly. Rather it is assumed that the flows can be combined and represented as a single flow over time. Furthermore, sectoral allocation of private direct investment is assumed to be controlled or taken into account so that it is compatible with the domestic development program.

Balance of Payments Adjustment Mechanisms

Several types of adjustment mechanisms can be simulated and comparisons were made between the effects of the different types used. Only one type, of course, was used on a given run. These adjustment mechanisms are actually policies instituted and directed

by a central authority; they are in the nature of a calculated response to some "feedback" signal. For this reason the discussion of these policies is left to the chapter on Controls, Chapter 9.

Parameter Values

The parameters in the demand curve for consumers' imports are discussed in the section on the Consumers' Joint Demand function and will not be repeated here.

The food import policy has only one parameter, THET2. A value is selected for THET2 so that per capita consumption of food does not fall and so that food imports will be eliminated in ten to fifteen years, given the development program for the agricultural sector.

The value for Q73 was determined from the input-output table by dividing the initial value of intermediate goods imports into sector 3 by the current value of sector 3's output. This gave a value of 0.2 for Q73. Thus Q73 functions as an input-output coefficient where the required input is an import.

Data from the input-output table was used to find values for the coefficients Q18 and Q28 which divide the export good between sector 1 and sector 2. Originally exports were present in both sectors but these were aggregated in order to have only one export demand equation. The value-added component of the sector 2 exports was combined with the sector 1 exports. The resulting figure taken as a proportion of total exports gave a value of 0.54 for Q18; Q28 under our assumptions is of course $(1 - Q18)$ or 0.46.

The elasticity of demand for the export good, $ELEX8$, is a parameter for which various values are tried. The other parameter in the export demand equation, $CHI8$, is adjusted to establish the correct initial value for exports, $EXF8$. Thus $CHI8$ is changed as necessary when a new value is used for $ELEX8$.

APPENDIX TO CHAPTER 7

DEFINITIONS OF VARIABLES IN FOREIGN SECTOR

BPD	Balance of payments in domestic currency (billions of rupees per year).
BPF	Balance of payments in foreign currency (billions of dollars per year).
EXD8	Value of exports in domestic currency (billions of rupees per year).
EXF8	Value of exports in foreign currency (billions of dollars per year).
FCAP	Net inflow of foreign capital (billions of dollars per year).
FXR	Foreign exchange reserves (billions of dollars).
IMD7	Value of capital and intermediate goods imports in domestic currency (billions of rupees per year).
IMF2	Value of food imports in foreign currency (billions of dollars per year).
IMF6	Value of consumer imports in foreign currency (billions of dollars per year).
IMF7	Value of capital and intermediate goods imports in foreign currency (billions of dollars per year).
LNPF8	Intermediate variable used in determining QEX8.
NEXP	Intermediate variable used in determining QEX8.
PF2	Foreign price of food imports (billions of dollars per quant).
PF6	Foreign price of consumer imports (billions of dollars per quant).
PF7	Foreign price of capital and intermediate goods imports (billions of dollars per quant).

- PF8 Price of exports in foreign currency (billions of dollars per quant).
- P6 Price of consumer imports including tariff in domestic currency (billions of rupees per quant).
- P7 Price of capital and intermediate goods imports including tariff in domestic currency (billions of rupees per quant).
- P8 Price of exports in domestic currency (billions of rupees per quant).
- QEX8 Quantity of exports (quants per year).
- QIMA2 Intermediate variable used in determining QIM2.
- QIM2 Quantity of food imports (quants per year).
- Q6 Quantity of consumer imports (quants per year).
- T6 Ad valorem tariff rate on consumer imports (no dimensions)--determined in Control Sector, Chapter 9.
- T7 Ad valorem tariff rate on capital and intermediate goods imports (no dimensions)--determined in Control Sector, Chapter 9.
- XR Foreign currency exchange rate (rupees per dollar).
- XRD Exchange rate determined by devaluation policy (rupees per dollar)--see Chapter 9.
- XRF Flexible exchange rate for consumer imports used in multiple exchange rate policy (rupees per dollar)--see Chapter 9.

DEFINITIONS OF CONSTANTS USED IN FOREIGN SECTOR

- CHI8 Parameter in export demand equation.
- DEVAL Devaluation policy selection indicator, used to isolate or incorporate the devaluation policy in each run (nondimensional)-- see Chapter 9.
- ELEX8 Price elasticity of demand for exports (nondimensional).
- NKB2 Initial value of productive capacity in sector 2 (land units).
- Q18 Quants of Q1 per quant of Q8 (quants per quant).
- Q28 Quants of Q2 per quant of Q8 (quants per quant).
- THEI2 Parameter in food import equation.

FOREIGN ACCOUNTS

EXPORTS

12R	P8.KL=(XR.K)(PF8.K)	EH7100
29A	LNPF8.K=(ELEX8)LOGN(PF8.K)	EH7101
28A	QEX8.K=(CHI8)EXP(LNPF8.K)	EH7102
22A	PF8.K=(1/XR.K)((Q28)(P2.JK)+(Q18)(P1.JK))	EH7103
12A	EXD8.K=(P8.JK)(QEX8.K)	EH7104
12A	EXF8.K=(PF8.K)(QEX8.K)	EH7105

IMPORTS

51A	QIM2.K=CLIP(QIMA2.K,0,QIMA2.K,0)	EH7119
16A	QIMA2.K=(1)(NQIM2)+(-THET2)(KB2.K)+(THET2)(NKB2)+(1)(0)	EH7120
6A	PF2.K=.2083	EH7121
12A	IMF2.K=(PF2.K)(QIM2.K)	EH7122
12A	IMD7.K=(Q7.K)(P7.JK)	EH7106
12A	IMF7.K=(Q7.K)(PF7.K)	EH7107
12A	IMF6.K=(Q6.K)(PF6.K)	EH7108
20A	Q6.K=C6.K/P6.JK	EH7109
6A	PF6.K=.2083	EH7110
6A	PF7.K=0.2083	EH7111
17R	P6.KL=(XR.K)(PF6.K)(1)+(XR.K)(PF6.K)(T6.K)+(0)(0)(0)	EH7112
NOTE	IN THE RUNS USING THE MULTIPLE EXCHANGE RATE POLICY THE TERM	
NOTE	(XR.K) IN EH7112 WAS REPLACED BY (XRF.K)	
17R	P7.KL=(XR.K)(PF7.K)(1)+(XR.K)(PF7.K)(T7.K)+(0)(0)(0)	EH7113
16A	XR.K=(DEVAL)(XRD.K)+(4.8)(1)+(-DEVAL)(4.8)+(1)(0)	EH7114

BALANCE OF PAYMENTS

10A	BPF.K=EXF8.K+FCAP.K-IMF2.K-IMF6.K-IMF7.K+0	EH7115
12A	BPD.K=(XR.K)(BPF.K)	EH7116
6A	FCAP.K=0.0	EH7117
1L	FXR.K=FXR.J+(DT)(BPF.J+0)	EH7118

INITIAL CONDITIONS AND CONSTANTS		
6N	FXR=3.0	EH7123
6N	P6=1.0	EH7124
6N	P7=1.0	EH7125
6N	P8=1.0	EH7126
28N	CHI8=(NQEX8)EXP(NEXP)	EH7131
29N	NEXP=(-ELEX8)LOGN(NPF8)	EH7132
6N	NPF8=.2083	EH7133
6N	NQEX8=7.02	EH7134
C	Q28=.46/Q18=.54	EH7127
C	DEVAL=0.0 =1 TO INCORPORATE DEVALUATION POLICY / =0 TO ISOLATE	EH7128
C	ELEX8=-1.5	EH7129
C	NQIM2=2.25/NKB2=61.78/THET2=.1	EH7130

CHAPTER 8

INCOME ACCOUNTS AND PRICE INDEXES

Income

In this section are derived the equations necessary for computing the principal national income variables, such as GNP, disposable income, YD, and business savings, BS, in current value terms. The basic assumptions regarding the abstraction from other financial aspects and from inventory changes have previously been set forth and will not be repeated here.¹

In the production of goods for consumption and export the incomes earned are equal to the market value of the goods sold less the expenditure for imported materials. Incomes earned in capital formation are equal to the total outlay for investment less the expenditure for imported capital goods; the value of capital goods produced is included in investment outlays. In addition incomes are earned by providing services to the government for administrative purposes; government commercial enterprises are accounted for in the same manner as private enterprises. Government administrative expenditures, GOV, is the only component of GNP which originates in

1. See Chapter 3, especially p. 29 and p. 39.

these accounts, since for lack of a more rational basis it is assumed to be proportional to GNP. The equation for GNP is:

$$8.01) \text{ GNP} = C1 + C2 + C4 + CVT + C6 + INVT + GOV + EXD8 \\ - CIM2 - IMD6 - IMD7$$

Where: GOV = (G)(GNP); G is a parameter.
 Ci = value consumed of good i.
 CVT = total value of services consumed.
 INVT = total investment in sectors 1-5.
 EXD8 = exports in domestic currency.
 IMDi = imports of good i in domestic currency,
 including any tariff.
 CIM2 = the quantity of food imports valued at P2.

The only departure from conventional income accounting is in valuing food imports at the domestic market price, P2, rather than the foreign price expressed in domestic currency. This is done because it is assumed that the government acts as the intermediary for food imports; it buys the food at world prices but sells it at the going market price. Any profits or losses are assumed to be absorbed in the government budget and are not explicitly accounted for.

From GNP are subtracted income taxes, profit taxes, and business savings to obtain disposable income, YD. A first approximation for personal taxes based on income is made as a constant proportion, TAX, of GNP. A second deduction from GNP accounts for depreciation, (which was not allowed for in computing gross profits, PROFi),

earnings retained in businesses, and business profit taxes, as well as for a higher savings rate and higher tax rate assumed to apply to those who receive the profit income. All of these effects are lumped together under the name "business savings," BS, and approximated by a constant fraction, SIGMi, of gross profits.

The quantity, then, that goes into the consumers' demand function is actually disposable income less profit taxes and savings above the ordinary rate by profit earners. However, it is labeled simply "disposable income." Its formulae are:

$$8.02) \quad YD = (1 - TAX - VTAX)(GNP) - BS \quad \text{Billion Rs./yr.}$$

$$8.03) \quad BS = \sum_{i=1,3,4,5} (SIGMi)(PROFi)$$

Where: TAX = the normal tax rate.
 VTAX = a variable tax associated with an inflation control policy. It is identically zero unless it is explicitly noted in a run that this policy is being used.
 SIGMi = the sum of the profit tax and excess savings rate.
 PROFi = gross profit.

Parameter Values

To estimate G. the average value of (government administrative expenditures)/(net output)¹ for the years 1950-51 to 1955-56 was taken. This gave G = .06.

1. Estimates of National Income, issued by General Statistical Organization, Cabinet Secretariat, Government of India, March 1958.

Estimates of the SIGMi's could not be made from data that included all firms in each sector because such comprehensive data does not exist to our knowledge. For sectors 1 and 2 data covering allocations of profits in selected industries was used to give a very rough value for SIGM1 and SIGM3.¹ The values used are: SIGM1 = .5, SIGM3 = .5

For sector 4, the small-scale industries, the difference between profits and wages is very obscure since it is difficult to distinguish between profits and wages in small self-owned-and-operated enterprises. For lack of necessary data the value of SIGM4 was set arbitrarily at .35.

In sector 5 the majority of the firms are state owned, e.g. railways. For our purposes the profits of these government owned firms are another part of the government revenue and are not explicitly identified. In these firms their SIGMi is equal to unity since no profits are distributed to individuals. A result of this government ownership is to make SIGM5 higher than either SIGM1 or SIGM3. On the basis of this limited information, a value of .73 was selected.

1. See Reserve Bank of India Bulletin, January 1957, Table 4, p. 4. This gives distributed profits as a percentage of profits before tax (1.0-Column 7 value) for selected industries during the five years, 1950-54. The following industries were taken as representative of the sector indicated:

<u>Sector 1</u>		<u>Sector 3</u>	
Cotton Textiles	Jute Textiles	Iron and Steel	Engineering
Other Textiles	Sugar	Cement	Chemicals
Paper	Vegetable Oil	Coal	

A value of .02 for TAX or .98 for ATP was selected on the basis of averaging the direct taxes as a percentage of private income for the years 1948-49 to 1955-56.¹

Deflated Variables

Since this model incorporates variable prices it is necessary to deflate aggregate variables such as GNP and disposable income in order to measure "real" changes in aggregate output and income. For this purpose an index of the consumers' domestic price level, PIX9, is used. Its formal derivation is given later in this chapter. This index is used to deflate the major portion of GNP, that is, all components except total investment, INVT, and imported capital and intermediate goods, IMD7. INVT is deflated by an index composed only of the price of capital in Sector 1, PK1, while IMD7 is deflated by P3, the price of capital and intermediate goods. For the additional accuracy obtained it was not felt worthwhile to use more elaborate indexes to deflate these two smaller components, INVT and IMD7, nor to use a different index for consumer imports. To obtain a measure of "real" GNP, RGNP, these three deflated components are then summed as follows.

1. See Estimates of National Income, 1948-49 to 1956-57 issued by Central Statistical Organization, Cabinet Secretariat, New Delhi, March 1958, p. 5.

$$8.04) \text{ RGNP} = \frac{(C1 + C2 + C4 + CVT + GOV + EXD8 - CIM2)}{\text{PIX9}} + \frac{(\text{INVT})}{\left(\frac{\text{PK1}}{2.7}\right)} - \frac{(\text{IMD7})}{\left(\frac{\text{P3}}{1.0}\right)} \quad \text{Billion Rs/yr.}$$

Where the initial value of PK1 = 2.7
and the initial value of P3 = 1.0

PIX9 is also used to form the following smoothed measure of real per capita income:

$$8.05) \text{ YPCAP} = \frac{\text{YC}}{(\text{POP})(\text{PIX9})} \quad \text{Rs/person/yr.}$$

Where YC is the lagged value of disposable income, YD.

Price Indexes

Two weighted indexes are used in the model; they are: the index of the consumers' domestic price level PIX9, the use of which was discussed above, and a measure of the current rate of change of the consumers' domestic price level, RINF9. Government policy is assumed to be sensitive to the problem of inflation; thus, for purposes of inflation control a quantitative measure of the current rate of inflation is required. The measure used for this purpose is RINF9. Since PIX9 is derived from RINF9 the latter will be formulated first.

The rate of change of the price level of consumer goods is proportional to the following:¹

1. This general form is discussed in F. C. Mills, Statistical Methods, New York, Holt & Co., 1938, p. 204.

$$8.06) \quad RINA9 = \frac{\sum (Q_{i_{t-\tau}} + Q_{i_t}) P_{i_t}}{\sum (Q_{i_{t-\tau}} + Q_{i_t}) P_{i_{t-\tau}}} \quad ; \quad i = 1,2,4,5$$

where $Q_{i_{t-\tau}}$ is a moving average of Q_i over a period of .25 years with the end of the period at $(t-\tau)$; Q_{i_t} , $P_{i_{t-\tau}}$, and P_{i_t} are similar moving averages ending at t or $(t-\tau)$ as indicated by the subscript. The parameter τ has dimensions of years and unless otherwise noted its value is set at .05 years.

The quantity RINA9 is the ratio of a weighted sum of prices at time t to the corresponding sum τ year earlier. Thus $(RINA9-1)$ is the increment over τ years as a proportion of the value of the weighted sum τ years previously. For an inflation index, RINF9, we convert this proportional growth rate $(RINA9-1)$ per τ units into an annual rate.

$$8.07) \quad RINF9 = (1/\tau)(RINA9-1)$$

By multiplying our proportional growth rate per year, RINF9, by PIX9 we obtain RPIX9, the annual rate of change of PIX9.

$$8.08) \quad RPIX9 = (RINF9)(PIX9)$$

From 8.08, PIX9 is obtained directly:

$$8.09) \quad PIX9 = 1.0 + \int_0^t (RPIX9) dt$$

APPENDIX TO CHAPTER 8

DEFINITIONS OF VARIABLES IN THE INCOME ACCOUNTS

Definition (dimensions)

BS	Business savings (billions of rupees per year).
CIM2	Food imports valued at domestic market price (billions of rupees per year).
GOV	Government administrative expenditures (billions of rupees per year).
GNP	Gross national product (billions of rupees per year).
GNPA	Intermediate variable used in determining GNP.
INVT	Total investment (billions of rupees per year).
RGNP	Deflated GNP (billions of rupees per year).
RGNPA	Intermediate variable used in determining RGNP.
RGNPB	Deflated value of IMD7 (billions of rupees per year).
RGNPC	Deflated value of INVT (billions of rupees per year).
YD	Disposable income (billions of rupees per year).
YC	Smoothed disposable income (billions of rupees per year).
YPCAP	Real smoothed disposable income per capita (rupees per person per year).

DEFINITIONS OF CONSTANTS IN THE INCOME ACCOUNTS

G	Coefficient relating government administrative expenditures to GNP (nondimensional).
SIGMi	Proportion of gross profits of sector i withheld from disposable income (nondimensional).

TAX Normal tax rate (nondimensional).
 VTAX Variable tax rate (nondimensional).

DEFINITION OF VARIABLES USED IN THE DERIVATION OF THE PRICE INDEXES

PAVAi Sum of the P_i that prevailed in the last five periods (billions of rupees per quant).
 PAVBi Generic name defining the moving train of memory storage cells used to store the values of P_i that prevailed in the last six periods.
 PAVBi*j Stored value of the P_i that prevailed in the j^{th} previous period (billions of rupees per quant).
 PAVOi Average value of P_i over the five periods previous to the current period (billions of rupees per quant).
 PAVli Average value of P_i over the five previous periods including the current period (billions of rupees per quant).
 PIXOT Intermediate variable used in determining RINA9.
 PIXOi Intermediate variable used in determining RINA9.
 PIX1T Intermediate variable used in determining RINA9.
 PIXli Numerator term in text equation 8.06 for sector i .
 PIX9 Index of consumers' domestic price level (nondimensional).
 QAVAi Sum of the quantity weights that prevailed in each of the previous five periods (quants per year).
 QAVBi Generic name defining the moving train of memory storage cells used to store the quantity weights for sector i for the previous six periods.
 QAVBi*j Stored value of the quantity weight for sector i that prevailed in the j^{th} previous period. (quants per year).
 QAVi Intermediate variable used to define PIXOi and PIXli (quants per year).

RINA9 Intermediate variable used in determining RINF9.

RINF9 Rate of change of the consumers' domestic price level
(proportion per year).

RPIX9 Rate of change of PIX9 (index units per year).

INCOME ACCOUNTS

INCOME EQUATIONS

11A	GNP.K=C1.K+C2.K+C4.K+CVT.K+INVT.K+GOV.JK+GNPA.K+0	EH6000
9A	GNPA.K=EXD8.K-CIM2.K-IMD7.K+0	EH6001
10A	INVT.K=INV1.K+INV2.K+INV3.K+INV4.K+INV5.K+0	EH6002
12P	GOV.KL=(G)(GNP.K)	EH6003
12A	CIM2.K=(QIM2.K)(P2.JK)	EH6004
16A	YD.K=(-BS.K)(1)+(GNP.K)(1)+(GNP.K)(-TAX)+(GNP.K)(-VTAX.K)	EH6005
16A	BS.K=(SIGM1)(PROF1.K)+(SIGM3)(PROF3.K)+(SIGM4)(PROF4.K)+(SIGM5)(PR	EH6006
X1	OF5.K)	EH6006

INITIAL CONDITIONS AND CONSTANTS

6N	GOV=6.35	EH6010
C	SIGM1=.5/SIGM3=.5/SIGM4=.34/SIGM5=.73/G=.06/TAX=.02	EH6011

REAL INCOME EQUATIONS

8A	RGNP.K=RGNPA.K+RGNPB.K+RGNPC.K	EH6020
24A	RGPA.K=(1/PIX9.K)(GNP.K-INVT.K+IMD7.K+0+0+0)	EH6021
20A	RGNPB.K=-IMD7.K/P3.JK	EH6022
44A	RGNPC.K=(INVT.K)(2.7)/PK1.K	EH6023
42A	YPCAP.K=YC.K/((POP.K)(PIX9.K))	EH6024

CONSUMERS PRICE INDEX

37B	QAVB1=BOXLIN(6,.05)	EH1300
6A	QAVB1*1.K=Q1.K	EH1301
53A	QAVA1.K=SUM1(5,QAVB1)	EH1303
16A	QAV1.K=(.4)(QAVA1.K)+(-Q1.K)(.2)+(QAVB1*6.K)(.2)+(0)(0)	EH1304
37B	PAVB1=BOXLIN(6,.05)	EH1305
6A	PAVB1*1.K=P1.JK	EH1306
53A	PAVA1.K=SUM1(5,PAVB1)	EH1308
12A	PAV11.K=(PAVA1.K)(.2)	EH1309
40A	PAV01.K=PAV11.K+(1/5)(PAVB1*6.K-P1.JK)	EH1310
12A	PIX01.K=(QAV1.K)(PAV01.K)	EH1311
12A	PIX11.K=(QAV1.K)(PAV11.K)	EH1312
37B	QAVB2=BOXLIN(6,.05)	EH2300
6A	QAVB2*1.K=KB2.K	EH2301
53A	QAVA2.K=SUM1(5,QAVB2)	EH2303
16A	QAV2.K=(.4)(QAVA2.K)+(-Q2.K)(.2)+(QAVB2*6.K)(.2)+(0)(0)	EH2304
37B	PAVB2=BOXLIN(6,.05)	EH2305
6A	PAVB2*1.K=P2.JK	EH2306
53A	PAVA2.K=SUM1(5,PAVB2)	EH2308
12A	PAV12.K=(PAVA2.K)(.2)	EH2309
40A	PAV02.K=PAV12.K+(1/5)(PAVB2*6.K-P2.JK)	EH2310
12A	PIX02.K=(QAV2.K)(PAV02.K)	EH2311
12A	PIX12.K=(QAV2.K)(PAV12.K)	EH2312
37B	QAVB4=BOXLIN(6,.05)	EH4300
6A	QAVB4*1.K=QC4.K	EH4301
53A	QAVA4.K=SUM1(5,QAVB4)	EH4303
16A	QAV4.K=(.4)(QAVA4.K)+(-QC4.K)(.2)+(QAVB4*6.K)(.2)+(1)(0)	EH4304
37B	PAVB4=BOXLIN(6,.05)	EH4305
6A	PAVB4*1.K=P4.JK	EH4306
53A	PAVA4.K=SUM1(5,PAVB4)	EH4308
12A	PAV14.K=(PAVA4.K)(.2)	EH4309
40A	PAV04.K=PAV14.K+(1/5)(PAVB4*6.K-P4.JK)	EH4310
12A	PIX04.K=(QAV4.K)(PAV04.K)	EH4311
12A	PIX14.K=(QAV4.K)(PAV14.K)	EH4312
37B	QAVB5=BOXLIN(6,.05)	EH5300

6A	$QAVB5*1.K = QA5.K$		EH5301
53A	$QAVA5.K = \text{SUM1}(5, QAVB5)$		EH5303
16A	$QAV5.K = (.4)(QAVA5.K) + (-QA5.K)(.2) + (QAVB5*6.K)(.2) + (0)(0)$		EH5304
37B	$PAVB5 = \text{BOXLIN}(6, .05)$		EH5305
6A	$PAVB5*1.K = P5.JK$		EH5306
53A	$PAVA5.K = \text{SUM1}(5, PAVB5)$		EH5308
12A	$PAV15.K = (PAVA5.K)(.2)$		EH5309
40A	$PAV05.K = PAV15.K + (1/5)(PAVB5*6.K - P5.JK)$		EH5310
12A	$PIX05.K = (QAV5.K)(PAV05.K)$		EH5311
12A	$PIX15.K = (QAV5.K)(PAV15.K)$		EH5312
9A	$PIX1T.K = PIX11.K + PIX12.K + PIX14.K + PIX15.K$		EH9600
9A	$PIX0T.K = PIX01.K + PIX02.K + PIX04.K + PIX05.K$		EH9601
20A	$RINA9.K = PIX1T.K / PIX0T.K$		EH9602
21A	$RINF9.K = (1/.05)(RINA9.K - 1)$	RATE OF INFLATION INDEX	EH9603
12A	$RPIX9.K = (RINF9.K)(PIX9.K)$	RATE OF CHANGE OF PIX9	EH9604
1L	$PIX9.K = PIX9.J + (DT)(RPIX9.J + 0)$	CONSUMERS PRICE INDEX	EH9605
	INITIAL CONDITIONS AND CONSTANTS		
C	$QAVB1* = 0/13.78/13.78/13.78/13.78/13.78$		EH1302
C	$PAVB1* = 0/1/1/1/1/1$		EH1307
C	$QAVB2* = 0/61.78/61.78/61.78/61.78/61.78$		EH2302
C	$PAVB2* = 0/1/1/1/1/1$		EH2307
C	$QAVB4* = 0/8/8/8/8/8$		EH4302
C	$PAVB4* = 0/1/1/1/1/1$		EH4307
C	$QAVB5* = 0/7.44/7.44/7.44/7.44/7.44$		EH5302
C	$PAVB5* = 0/1/1/1/1/1$		EH1307
6N	$PIX9 = 1.0$		EH9606

CHAPTER 9

POLICIES AND CONTROLS

Operating on the system of production, distribution, etc., described in foregoing chapters, are various governmental controls. In the specification of conditions for each computer run, details of how these are to operate must be spelled out. Because the study for which this model has been used was in large part an exploration of policies, a variety of alternative policies have been formulated and are described in this chapter. Many of these have not been used in all runs, and some have been used in only a few.

Most of this chapter is devoted to descriptions of policy controls of a type which are invoked only if particular problems develop. Some are adjusted in proportion to the current severity of the situation with which they are intended to cope. These are what the engineer calls "feedback" controls because they are responsive to information which is "fed back" from the problematic situation to indicate how nearly the control is achieving the desired result. In the economic system, of course, these are not presumed to act automatically, but are intended to represent the effects of decisions made by human policy-makers and administrators.

Another sort of control that is used is the pre-established time-profile of capital formation in certain sectors and of minimum limits on capital formation in others. These programmed time-profiles represent the execution of a long-range development plan, not primarily determined by current problems at any point (although parts of the long-range plan may be overridden by measures to cope with short-run crises.) Variations in these time profiles were a primary concern in one part of the study.

Investment Controls

The concept of investment control as used in this model is a limited one in that control is limited to real variables; the financial incentives or restrictions necessary to affect the real variable are ignored. To make this clear, let us consider the general problem of restricting investment. A government has several methods available to accomplish this, such as tight money, taxes on capital goods, licensing, etc. all of which are merely means of controlling the "real" rate of investment. In the model the particular means used to accomplish the desired change in real investment is not made explicit nor even implicit. Rather it is assumed that some effective means can be and are found. In general, the controls act, in any sector, by altering the rate of starting capital-creation projects, which has a lagged effect on the level of real investment in the sector.

The five producing sectors of the model can be divided into two groups: one group in which the investment decision is made by private

investors, subject to government limitations, and the other group where it is made solely by the government. In the latter group are sectors 2, 4, and 5. In sectors 2 and 4, and sometimes sector 5, the rate of starting new capital projects, $RKSi$, is programmed as an exogenous function of time. In sector 5, during some series of runs, $RKS5$ was determined by a feedback control sensitive to the demand for the sector's output. The exact forms of the exogenous functions are an integral part of the "development plan" being investigated in a given run.

The remaining sectors, 1 and 3, are those where private investors determine a desired rate of starting new capital projects, $DRKSi$, on the basis of an investment decision function, the arguments of which are profits, replacement needs, and capital in gestation.¹ This desired rate of starts may then be modified by government policy in a manner described below. In some cases the planned program for sector 5 was similarly modified. Investment controls may be invoked against either insufficient or excessive investment.

Underinvestment in a private sector exists when the investors' desired rate of starting projects falls below a minimum or floor value of $RKSi$, called $FRKSi$, which is set by government policy. A time profile of $FRKSi$ is specified for sectors 1 and 3 by the development plan. Whenever the investment decision function yields

1. See Chapter 5, Section A, for a complete description of the investment decision function.

a desired rate of starting capital projects below the floor value for that time, the desired rate is ignored and the programmed floor value is substituted:

$$9.01) \quad PRKSi = \max (DRKSi; FRKSi) \quad i = 1,3$$

This new variable, equal to the desired rate or the floor rate, whichever is larger, is called the "planned rate of starting new capital projects." If no problem exists calling for restraining investment, this will become the actual rate of starts, $RKSi$. If, however, "overinvestment" is deemed to exist, the planned rate may be reduced, as described below.

Overinvestment is not defined sector by sector but only for the economy as a whole. Overinvestment in this sense manifests itself in general inflation and/or a loss of foreign exchange reserves. We assume that investment may be restricted to combat either inflation or a foreign exchange crisis. It is recognized that either of these symptoms may also indicate "overconsumption" defined in some sense, as well as overinvestment. In a few runs the problem was attacked from this side through income tax increases; in others, limitation of wage increases was used to slow down the "cost-push" effect and bias income distribution somewhat in a direction that yields higher taxes and savings. Nevertheless, in this study emphasis was mainly on investment control, since most investment is already assumed to be under government control, and since, at the low level of per capita

income which initially prevails, it is not considered feasible to reduce consumption very far by government action.

For purposes of control an inflation problem is defined to exist when the rate of change of the consumers' price level, $RINF9$, exceeds a limit, $MANF$, which is set by government policy. For purposes of investment control a foreign exchange crisis is defined to exist when the level of foreign exchange reserves falls below an amount necessary to finance the current deficit for $FXR9$ years, where $FXR9$ is a parameter. More precisely, a foreign exchange crisis exists when $NFXR9$ is negative:

$$9.02) \quad NFXR9 = FXR + (FXR9)(BPF)$$

Where FXR = Foreign exchange reserves.

BPF = Balance of payments in foreign currency.

Investment control may then be invoked either by an inflation or foreign exchange problem. In a given run investment controls are made to respond to either problem depending upon which value has been specified for following "selection" parameters:

$CINF9 = 1$ if investment controls are to be used for inflation control, or $= 0$ if not to be used for this purpose.

$CFXR9 = 1$ if investment controls are to be used for foreign exchange control, or $= 0$ if not to be used for this purpose.

Before giving the details of the control mechanism for combatting overinvestment it will be useful to present the general procedure as

this is somewhat more complicated than that used to meet underinvestment. In this case the target variables are the money value of investment in each sector, INV_i , but each of these variables is only controlled indirectly by modifying the appropriate $PRKSi$. First, a ceiling value is selected for each INV_i , designated $CINV_i$, and then by controlling $PRKSi$, INV_i is gradually reduced until it is equal to the specified ceiling. Thus there is a significant delay between the need for action, i.e., the imposition of a ceiling, and the completion of the action; i.e., when the error between INV_i and $CINV_i$ is eliminated. The details of how a ceiling is selected and implemented by changing $PRKSi$ will now be explained for one sector. The procedure is the same for all sectors which are controlled.

When an inflation problem or foreign exchange crisis comes into existence a ceiling on the money value of investment, INV_i , is selected. This ceiling is $(PC_i \times 100)$ per cent of the INV_i which prevailed at the time that the problem arose; the first ceiling value prevails for a specified interval, $WAIT_9$. When $WAIT_9$ has elapsed, if the problem still exists, the ceiling is lowered to $(PC_i \times 100)$ per cent of current INV_i . This second ceiling again prevails for an interval equal to $WAIT_9$. This procedure of periodically reducing the ceiling continues as long as a problem exists.

This procedure is expressed in the following equation:

$$9.03) \quad CINV_i_t = (PC_i)(INV_i)_{\tau + n(WAIT_9)}$$

Where: τ = the value of t when the current inflation or foreign exchange problem began.

$n = 0, 1, 2 \dots$ such that the following holds:

$$n(WAIT_9) < t - \tau \leq (n+1)(WAIT_9)$$

PC_i = a parameter between 0 and 1.

This describes when and how the ceiling is selected and adjusted. Actual investment, INV_i , however, cannot simply be cut instantly to the ceiling level. The ceiling is assumed to affect only future capital projects, i.e., projects upon which construction has not yet begun. Any capital in the gestation phase will be completed regardless of whether a ceiling exists on INV_i . This leaves the rate of starting new capital projects, RKS_i , as the variable that must be controlled in order to reduce actual investment. Recall the equations for INV_i and KG_i , developed in Chapter 5 (A).

$$9.04) \quad INV_i = (KG_i)(PK_i)/G_i$$

$$9.05) \quad KG_i = (KG_i)_{t=0} + \int_0^t (RKS_i - RKP_i) dt$$

Where KG_i = the amount of capital in real units under construction, i.e. in gestation.

PK_i = the price of real capital in sector i .

G_i = the gestation period of new capital in sector i .

RK_{Pi} = the rate of finishing new capital in sector i .

Differentiating 9.04:

$$9.06) \quad d(INV_i)/dt = \frac{1}{G_i} \left\{ (PK_i)(RKS_i - RK_{Pi}) + (KG_i) \left[\frac{d(PK_i)}{dt} \right] \right\}$$

When a ceiling is in effect we define the error, $EINV_i$, as:

$$9.07) \quad EINV_i = (CINV_i - INV_i)$$

A feedback control is constructed by defining a controlled RKS_i , designated $CRKS_i$, with is related to the error as follows:

$$9.08) \quad CRKS_i = \frac{(G_i)(EINV_i)}{(PK_i)(UPS_i)} + RK_{Pi}$$

Where UPS_i is a time constant.

Actual RKS_i is constrained to be equal to or less than $CRKS_i$. When they are equal, 9.06 becomes:

$$9.09) \quad d(INV_i)/dt = (1/UPS_i)(EINV_i) + (KG_i/G_i) \left[\frac{d(PK_i)}{dt} \right]$$

This also implies:

$$9.10) \quad d(KG_i)/dt = (1/UPS_i)(EINV_i)(G_i/PK_i)$$

Thus the ceiling control is made effective by changing $d(KGi)dt$ and hence KGi . If $d(PKi)/dt = 0$ then INV_i will exponentially approach the selected ceiling. If initially $INV_i = CINV_i$ and then $d(PKi)/dt$ becomes greater than zero this will increase the money value of INV_i which in turn will create a negative error term. The error term will cause a reduction in $CRKSi$, and hence in KGi , thus correcting INV_i . For decreasing PKi the process is reversed.

Now to recapitulate briefly, in this section we have defined a "planned" $PRSi$ which corrects the investors' "desired" $RKSi$ if this desired rate falls below $FRKSi$, the programmed floor for $RKSi$. Further there is a "controlled" $RKSi$ which overrides either $DRKSi$ or $FRKSi$, if an inflation or foreign exchange problem exists. This selection process determining the actual $RKSi$ can be described as follows:

$$9.11) \quad PRKSi = \max [DRKSi, FRKSi]$$

If the ceiling controls are inoperative:

$$9.12A) \quad RKSA_i = PRKSi$$

If the ceiling controls are operative.

$$9.12B) \quad RKSA_i = \min [PRKSi, CRKSi]$$

And finally:

$$9.13) \quad RKSi = \max [RKSA_i, 0]$$

The selection 9.12B implies that the ceiling controls only operate to reduce $PRKSi$ to the controlled value, so if $PRKSi$ falls below the controlled value the ceiling controls, even if still operative, are no longer constraining.

Wage Controls

Wage controls are formulated as an alternative means of controlling inflation. The controls apply only to the wages in the industrialized sectors, 1, 3, and 5. Wage increases in these sectors are normally a function of profits, and decreases are assumed not possible. When this policy is chosen, the wage controls operate whenever $RINF9$, the rate of increase of the consumers' price level, exceeds a preselected maximum. Two alternative degrees of wage control are postulated. The first limits the rate of increase of wages to the rate equivalent to $RINF9$; that is, wages are allowed to increase, but no faster than the cost of living. The second and more stringent policy imposes an absolute moratorium on wage increases so long as the rate of increase of the consumers' price level exceeds the specified maximum. On a given run only one, if either, of the two policies is used.

In any sector to which these policies apply, the cost-of-living wage control operates as follows. The "desired" rate of increase of the wage rate,¹ expressed in proportionate terms--i.e., as an own

1. Determined by the profit rate, as postulated in Chapter 5 (A).

rate of growth--is compared with the inflation index. If the desired own rate, DR_{Wi} , exceeds the rate of inflation, $RINF9$, while the latter is above its allowable value, $MANFi$, then the rate of increase of wages is cut down to match the inflation index. If the desired rate is lower, or if the inflation index is below its limit, the desired rate prevails. This is expressed symbolically as follows:

$$9.14) \quad CRW_{Ai} = \begin{cases} (RINF9)(W_i) & \text{if } DR_{Wi} > RINF9 \\ \text{Desired rate} & \text{if } DR_{Wi} \leq RINF9 \end{cases}$$

$$9.15) \quad R_{Wi} = \begin{cases} CRW_{Ai} & \text{if } RINF9 \geq MANFi \\ \text{Desired rate} & \text{if } RINF9 < MANFi \end{cases}$$

$$9.16) \quad W_i = W_i(t=0) + \int_0^t (R_{Wi}) dt$$

For the more stringent policy, Equations 9.14 and 9.15 are replaced by the following, used in conjunction with 9.16:

$$9.17) \quad R_{Wi} = \begin{cases} 0 & \text{if } RINF9 \geq MANFi \\ \text{Desired rate} & \text{if } RINF9 < MANFi \end{cases}$$

(The mechanics of making this substitution consist in multiplying CRW_{Ai} by a control constant, CW_i , which may be made equal to 1 to give Equation 9.15, or 0 for 9.17. To eliminate wage controls entirely, the allowable inflation rate, $MANFi$, is simply assigned a value higher than $RINF9$ will ever reach.)

Variable Income Tax

Another mechanism that has been used for inflation control in the model is an income tax whose rate is continuously adjusted according to the severity of the inflation problem. This is not proposed as a feasible policy in practice. The purpose of simulating such a control is to determine what increase in tax rate would be required in certain situations to make a tax policy effective in controlling inflation. This can then serve as a reference point for consideration of practical tax policies.

With this policy the basic income tax rate remains as a minimum, but to it is added, as necessary, a variable tax. The rate of increase of this variable tax is proportional to the difference between the current rate of increase of the consumers' price level, $RINF9$ and the prescribed maximum allowable rate of inflation, $MANF$. The rate of decrease of the variable tax is proportional to the difference between $RINF9$ and $(MANF - .005)$; this implies that once the variable tax has been increased no effort is made to lower it until the rate of inflation has fallen one half per cent below the maximum allowable value. Further, the speed of response for increasing the tax is twice as large as for decreasing the tax. The equations for the variable tax, $VTAX$, follow:

$$9.18) \quad VTAX = \int_0^t (RTP + RTN) dt; \quad \geq 0$$

$$9.19) \quad RTP = (ROEI6)(RINF9 - MANF); \quad \geq 0$$

$$9.20) \quad RTN = (ROED6)(RINF9 - MANF + .0C5); \quad \leq 0$$

Where ROEI6 and ROED6 are speed-of-response coefficients, or, equivalently, the reciprocals of time constants.

Devaluation Policy

This policy calls for a devaluation of the exchange rate by a fixed percentage at periodic intervals whenever a foreign exchange crisis exists. The definition of a foreign exchange crisis used here is the same as that given in the section on investment controls except that the parameter value may differ. That is, with regard to the devaluation policy a foreign exchange crisis exists whenever NFXR7 is negative:

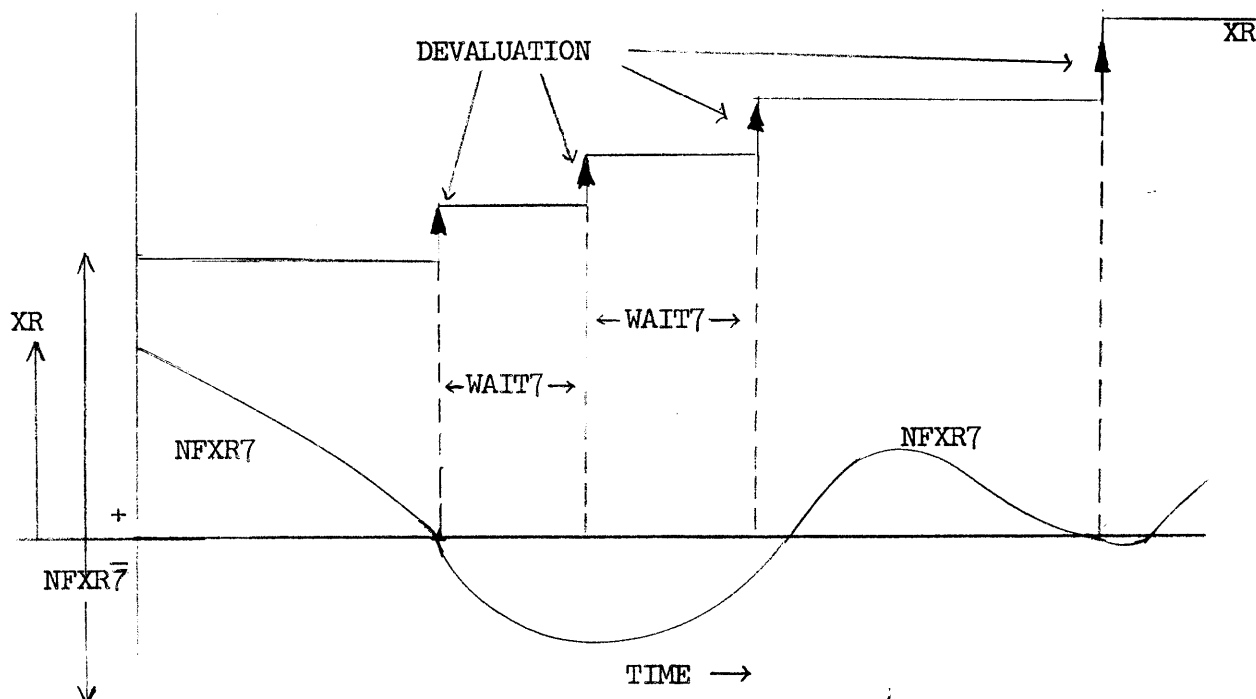
$$NFXR7 = FXR + (FXR7)(BPF)$$

Where FXR7 is a parameter.

When a crisis first occurs a devaluation of PCDEV per cent takes place after a fixed delay of WATA7 years, which is usually set at one computation period (DT = .05 years). Following this initial devaluation no further action is taken for a set period, defined as WAIT7. At the end of WAIT7 years if NFXR7 is still negative another devaluation of the same percentage, PCDEV, occurs. In absolute units each increase in exchange rate will be larger than the previous one as the fixed percentage is applied to the current value of the exchange

rate. This adjustment of the exchange rate continues every $WAIT_7$ years so long as $NFXR_7$ remains negative. When $NFXR_7$ becomes positive the process stops. If a foreign exchange crisis recurs, then the process begins again, but in no case are devaluations made more often than every $WAIT_7$ years.

The diagram below summarizes the above description:



No provision is made for appreciation of the exchange rate. It is assumed that a level of FXR high enough to warrant appreciation implies that the development program is too weak.

Tariff Policy, 2000 Series

Two tariff policies are formulated, one of which is used in the 2000 series of runs and one of which is used in the 3000 series of runs. They are sufficiently different to warrant separate discussions.

The tariff policy used in the 2000 series comprises a protective ad valorem tariff, T7, on imports of capital and intermediate goods to prevent idle capacity from developing in sector 3, and an ad valorem tariff on consumer goods imports, T6, which is a function of the balance of payments. Each tariff is subject to adjustment twice a year to equal the value of a hypothetical "shadow" tariff. The shadow tariffs are continuous variables whose rates of change over time are linear functions of either idle capacity in sector 3 or the balance of payments, as appropriate. The shadow tariffs may increase or decrease but it is assumed that they can be more readily increased than decreased; that is, the time constants for increases are smaller than for decreases. Further it is assumed that the tariff on consumer imports will not be raised higher than necessary to make the price of imports including the tariff twice the price of the domestic substitute, Q1. Increases in T7 occur only as long as imports of the perfect substitute, Q7K, continue.

The equations for the shadow tariffs are:

$$9.21) \quad d(T6)/dt = - (ROE6)(BPF)$$

$$\text{Subject to: } 1 \leq (1 + T6) \leq 2(P1/P6')$$

Where: $P6'$ is the import price without tariff, in domestic currency, and

$$ROE6 = \begin{cases} ROEI6 & \text{if } BPF < 0 \\ ROED6 & \text{if } BPF > 0 \end{cases}$$

$$9.22) \quad d(T7)/dt = - (ROE7) \left(\frac{QH3}{QB3} - 1.4 \right)$$

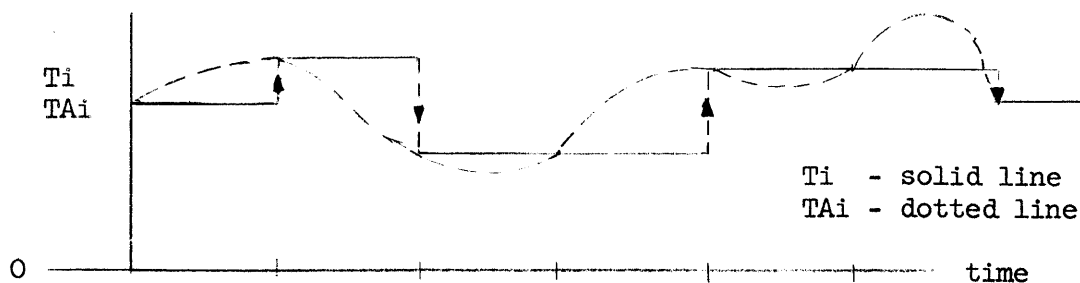
$$\text{Subject to: } 1 \leq (1 + T7) \leq 1.1 (P3/P7')$$

Where: $P7'$ is the import price without tariff, in domestic currency, and

$$ROE7 = \begin{cases} ROEI7 & \text{if } \left(\frac{QH3}{QB3} - 1.4 \right) < 0 \\ ROED7 & \text{if } \left(\frac{QH3}{QB3} - 1.4 \right) > 0 \end{cases}$$

$ROEI6$ and $ROED6$ are the reciprocals of the time constants for increasing $T6$ and $T7$ respectively. $ROED6$ and $ROED7$ are the reciprocals of the time constants for decreasing $T6$ and $T7$ respectively.

The relationship between the tariff rates $T6$ and $T7$ and their respective shadow tariffs is shown graphically in the following diagram:



Tariff policy, 3000 series

The tariff policy used in the 3000 series was designed exclusively to conserve foreign exchange reserves. The ad valorem tariffs T_6 and T_7 are raised, if the situation warrants, in finite steps of pre-established magnitude with definite waiting intervals. Decreases are not provided for. The magnitudes of the steps are chosen to increase the prices (including tariff) by the same proportion each time. Thus P_6 and P_7 , the import prices, are each affected in the same way as when the devaluation policy is used. The principal difference from devaluation is that the foreign price of exports is not affected. Also, the two tariff rates are not necessarily equal. The consumer-goods tariff is not allowed to exceed a value making the resulting price, P_6 , twice the value of P_1 . Increases in T_7 are stopped if the imports of Q_7K fall to zero.

Multiple Exchange Rate Policy

This policy differs in its effect from the tariff policy of the 3000 series only in its impact on P_6 . The adjustments in P_7 , whether they are conceived of as being due to exchange rate or tariff adjustments, use the same equations as in the 3000 series tariff policy. Also as in the tariff policy, the price of exports is not directly affected by the policy. The price of consumer imports, P_6 , under the multiple exchange rate policy, is determined by a flexible exchange rate that applies only to P_6 although it is a function of the total balance of payments, BPF. This policy assumes

that the authorities have complete control over the foreign exchange earned by exports. Part of the foreign exchange is sold to importers of Q7K and Q7I at rates determined by policy. Another part is used to pay for food imports. The remainder is sold to consumers at the current exchange rate for consumer imports. This rate is adjusted by the authorities in an attempt to maintain zero balance of payments.

If the authorities continually set the consumers' exchange rate too low, a secular loss of foreign exchange reserves results until the reserves become insufficient to finance the current deficit for FXR7 years, that is, NFXR7 becomes negative. If this happens, the exchange rate for imports of Q7K and Q7I is stepped up by PCT7 per cent and at the same time the rate of change of the consumers' exchange rate becomes a function of NFXR7 as well as the balance of payments, BPF, until the reserves are restored to the desired level.

The equation for the consumer-goods flexible exchange rate is:

$$9.23) \quad d(XRF)/dt = RXRF = (- OMEG7)(NFXRF) + (- PSI7)(BPF)$$

$$\text{Where: } NFXRF = \begin{cases} NFXR7 & \text{if } NFXR7 < 0 \\ 0 & \text{if } NFXR7 > 0 \end{cases}$$

and: OMEG7 and PSI7 are reciprocals of time constants.

Quota Policy

The quota policy differs from the multiple exchange rate policy only in the way that consumer imports are controlled. The initial quota is set equal to the initial value of consumer imports, it is then

adjusted only downwards in discrete steps. Under the quota policy, when a foreign exchange crisis occurs (i.e. when $NFXR_7$ goes negative) the tariff on capital and intermediate goods imports, T_7 , is increased by PCT_7 per cent, and the quota on consumer imports is decreased by PCC_6 per cent. No provision is made either for decreasing T_7 or increasing the quota. Using the spacing criterion of the devaluation policy, so long as $NFXR_7$ remains negative the above adjustments take place each $WAIT_7$ years. The increases in T_7 cease, however, when Q_7K becomes zero.

The effects of the balance of payments policies that operate by changing the prices of imports or exports are summarized in the table on the following page.

IMPACT OF BALANCE-OF-PAYMENTS POLICIES

<u>Policy</u>	<u>Import Prices in</u> <u>Domestic Currency</u>		<u>Export Price in</u> <u>Foreign Currency</u>
	P6 (Consumer imports)	P7 (Capital and intermediate imports)	PF8 (Exports)
Devaluation:	Adjusted in steps via XRD.	Adjusted in steps via XRD.	Adjusted in steps via XRD.
Tariff:	Adjusted in steps via T6.	Adjusted in steps via T7. (if $Q7K > 0$)	Unchanged
Multiple exchange rate:	Continuously adjusted via XRF.	Same as above	Unchanged
Quota:	Constant P6, but quota re- duced in steps.	Same as above	Unchanged

APPENDIX TO CHAPTER 9

In the DYNAMO equations of this chapter many of the variables have no economic significance but are devices to achieve the desired effects specified in the verbal description of the controls. They are, therefore, meaningless out of the context of the DYNAMO equations; for this reason the alphabetic listing of variables contains only those variables that have meaning apart from the equations. For readers having a knowledge of the DYNAMO system the DYNAMO equations plus the notes accompanying them provide a complete explanation of how the effects discussed in the text were achieved. Explaining the DYNAMO system itself, however, is beyond the scope of this paper.

DEFINITIONS OF VARIABLES USED IN THE CONTROL EQUATIONS

- CINVi Current investment ceiling in sector i (billions of rupees per year).
- CRKSi The controlled rate of starting new plants in sector i as determined by the investment ceiling controls (plants per year).
- CRWi The controlled rate of change of W_i as determined by the wage controls (billions of rupees per labor unit per year).
- CRWai Minimum of the desired rate of increase or cost-of-living rate of increase of W_i (billions of rupees per labor unit per year).

- CRWBi The rate of increase of W_i which would be in proportion to the increase in the consumers' price level (billions of rupees per labor unit per year).
- DRWi The own rate of growth of W_i implied by DRW_{Ai} (proportion per year).
- DRW_{Ai} Desired rate of increase of W_i as determined by the normal wage assumptions (billions of rupees per labor unit per year).
- EINVi The difference (error) between the investment ceiling and the current value of investment in sector i (billions of rupees per year).
- FRKSi The minimum (floor) value of the rate of starting new plants in sector i allowed by the investment plan (plants per year).
- MC6 Current quota for consumer imports in value terms (billions of rupees per year).
- NFXRF Negative values only of NFXR₇ (billions of dollars).
- NFXRi Foreign exchange reserves net of the amount necessary to finance the current deficit for FXYR_i years (billions of dollars).
- PRKSi The planned rate of starting new plants in sector i , maximum of DRKSi and FRKSi (plants per year).
- RKSi The actual rate of starting new plants in sector i (plants per year).
- RTN Negative rates of change only of VTAX (nondimensional units per year).
- RTP Positive rates of change only of VTAX (nondimensional units per year).
- RWi Actual rate of change of W_i (billions of rupees per labor unit per year).
- RXRF Rate of change of XRF (rupees per dollar per year).
- T6 Ad valorem tariff rate on consumer imports (no dimensions).
- T7 Ad valorem tariff rate on imports of capital and intermediate goods (no dimensions).

- VTAX Variable income tax (no dimensions).
- XRD Foreign currency exchange rate determined by the devaluation policy (rupees per dollar).
- XRF Flexible foreign currency exchange rate as determined by the multiple exchange rate policy (rupees per dollar).

DEFINITIONS OF CONSTANTS USED IN THE CONTROL EQUATIONS

- CINF9 Investment control selection indicator: assigned the value one if investment controls are to be used as an anti-inflationary policy; assigned the value zero otherwise (nondimensional).
- CFXR9 Investment control selection indicator: assigned the value one if investment controls are to be used as a balance of payments policy; assigned the value zero otherwise (nondimensional).
- CWi Wage control selection indicator: assigned the value one if the cost-of-living wage controls are to be used in sector i; assigned the value zero if rigid wage limits are to be used (nondimensional).
- FXR7 Specifies the minimum number of years for which it is desired to be able to finance the current deficit out of foreign exchange reserves. This parameter is used in the Devaluation Policy and the Tariff Policy for the 3000 series runs (years).
- FXR9 Same as FXR7 but used with the investment controls (years).
- MANF Value of RINF9 above which an inflation problem is defined to exist. Used in the investment controls and the Variable Tax Policy (proportion per year).
- MANFi Value of RINF9 at which the wage controls in sector i become operative (proportion per year).
- NVTAX Tax policy selection indicator: assigned the value one if the Variable Tax Policy is to be used; assigned the value zero otherwise (nondimensional).
- OMEG7 Speed-of-response coefficient (reciprocal of the time constant) relating changes in XRF to NFXR7 (rupees-per-dollar per year per billion dollars).
- PCC6 Proportionate reduction in the quota on consumer imports at each adjustment.

- PCDEV Proportionate increase in the exchange rate at each devaluation.
- PCi Ratio of the investment ceiling in sector i to the value of actual investment at each time the ceiling is adjusted.
- PCTi Proportionate increase in T_i at each adjustment in the Tariff Policy for the 3000 series runs.
- PSI7 Speed-of-response coefficient relating changes in XRF to BPF (rupees-per-dollar per year per billion dollars-per-year).
- RHOI6 Speed-of-response coefficient for increases in T_6 in the Tariff Policy for the 2000 series runs (proportion per billion dollars).
- RHOI7 Speed-of-response coefficient for increases in T_7 in the Tariff Policy for the 2000 series runs (nondimension units per year).
- RINF9 Rate of change of the consumers' price level (proportion per year).
- ROED6 Speed-of-response coefficient for decreases in T_6 in the Tariff Policy for the 2000 series runs (proportion per billion dollars).
- ROED7 Speed-of-response coefficient for decreases in T_7 in the Tariff Policy for the 2000 series runs (nondimensional units per year).
- ROEDT Speed-of-response coefficient for decreases in VTAX.
- ROEIT Speed-of-response coefficient for increases in VTAX.
- TARIF Tariff policy selection indicator: assigned the value one if the Tariff Policy is to be used; assigned the value zero otherwise (nondimensional).
- UPSIi Time constant which applies to the correction of the error between the investment ceiling and the current value of investment in sector i (years).
- WAIT7 The minimum spacing between devaluations, tariff adjustments (3000 series runs), or quota reductions (years).
- WAIT9 The minimum spacing between reductions in investment ceilings (years).

CONTROL SECTOR EQUATIONS

EQUATIONS THAT DEFINE AN INFLATION PROBLEM OR FOREIGN EXCHANGE (FXR) CRISIS FOR PURPOSES OF INVESTMENT CONTROL.

15A	PROB9.K=(CINF9)(TINFL.K)+(CFXR9)(TNFXR.K) SIGNALS A PROB. IF POS.	EH9000
51A	TINFL.K=CLIP(1,0,RINF9.K,MANF) SIGNALS INFLATION PROBLEM IF =1	EH9001
51A	TNFXR.K=CLIP(2,0,0,NFXR9.K) SIGNALS FXR CRISIS IF =2	EH9002
14A	NFXR9.K=FXR.K+(FXR9)(BPF.K)	EH9003
51A	VARI9.K=CLIP(DT,100,CLA9.K,WAIT9) SELECTS NEW CEILING IF CL9=WAIT9	EH9004
14A	CLA9.K=CL9.K+(DT)(DCL9.K) PRE-COMPUTES NEXT VALUE OF CL9	EH9005

INITIAL CONDITIONS AND CONSTANTS

C	MANF=.02	EH9006
C	CINF9=0 SET=1 FOR INVESTMENT CONTROLS AS ANTI-INFLATION POLICY	EH9007
C	CFXR9=0 SET=1 FOR INVESTMENT CONTROLS AS BALANCE OF PAY. POLICY	EH9008
C	FXR9=4.5	EH9009

CEILING ADJUSTMENT TIMING EQUATIONS

1L	CL9.K=CL9.J+(DT)(DCL9.J+0) GIVES ELAPSED TIME SINCE LAST ADJ.	EH9010
51A	DCL9.K=CLIP(CLR9.K,CLQ9.K,CL9.K,WAIT9) SETS CL9=0 WHEN CL9=WAIT9	EH9011
20A	CLR9.K=-CL9.K/DT DECREMENT FOR RESETTING CL9 TO 0	EH9012
51A	CLQ9.K=CLIP(CLP9.K,1,CL9.K,WATA9) STOPS CL9 AT WATA9 IF NO PROB.	EH9013
51A	CLP9.K=CLIP(0,1,0,PROB9.K) STARTS CL9 IF PROB. EXISTS	EH9014

INITIAL CONDITIONS AND CONSTANTS

7N	WATA9=WAIT9-DT	EH9015
7N	CL9=WAIT9-DT	EH9016
C	WAIT9=1.0	EH9017

INVESTMENT CEILING EQUATIONS FOR SECTOR 1

51R	RKS1.KL=CLIP(RKSA1.K,0,RKSA1.K,0) KEEPS ACTUAL RKS POSITIVE	EH9101
51A	RKSA1.K=CLIP(PRKS1.K,CRKS1.K,0,PROB1.K) SELECTS CONTROLLED RKS IF	EH9102

NOTE A PROBLEM EXISTS AND IF CONTROLLED RKS WILL CONSTRAIN PRKS EH9102
51A $PRKS1.K = CLIP(DRKS1.K, FRKS1.K, DRKS1.K, FRKS1.K)$ SELECTS HIGHER OF EH9103
NOTE DESIRED RKS AND FLOOR RKS EH9103
7A $PROB1.K = PROB9.K + TRKS1.K$ SEE NOTES BELOW EH9104
NOTE $PROB1$ LESS THAN 0 IF CONTROLLED RKS IS NOT CONSTRAINING PRKS EH9104
NOTE $PROB1=0$ IF THERE IS NEITHER A FXR OR INFLATION PROBLEM EH9104
NOTE $PROB1=+1$ IF THERE IS ONLY AN INFLATION PROBLEM EH9104
NOTE $PROB1=+2$ IF THERE IS ONLY A FXR PROBLEM EH9104
NOTE $PROB1=+3$ IF BOTH PROBLEMS EXIST EH9104
51A $TRKS1.K = CLIP(-4, 0, CRKS1.K, PRKS1.K)$ =-4 IF CONTROLLED RKS IS NOT EH9005
NOTE CONSTRAINING PRKS EH9005
7A $CRKS1.K = CRKA1.K + RKP1.JK$ CONTROLLED RKS1 EH9106
46A $CRKA1.K = (G1)(EINV1.K)(1) / ((PK1.K)(UPS11)(1))$ FEEDBACK TO ADJUST EH9107
NOTE CONTROLLED RKS FOR ACTUAL INV1 GREATER THAN CEILING INV1 EH9107
7A $EINV1.K = CINV1.K - INV1.K$ ERROR BETWEEN INV1 CEILING AND EH9108
NOTE CURRENT VALUE OF INV1 EH9008
43A $CINV1.K = SAMPLE(PINV1.K, VARI9)$ CHANGES THE CEILING CONTINUOUSLY EH9109
NOTE WHEN CL9 IS CONSTANT (WHEN NO PROBLEM EXISTS) AND ONCE EACH EH9109
NOTE TIME THAT CL9 EQUALS WAIT9 EH9109
12A $PINV1.K = (INV1.K)(PC1)$ PROPOSES A NEW CEILING EACH DT EH9110

INITIAL CONDITIONS AND CONSTANTS

C $PC1 = 0.90$ EH9111
C $UPS11 = .25$ EH9112

INVESTMENT FLOOR EQUATIONS FOR SECTOR 1 USED IN THE 2000 SERIES RUNS

59A $FRKS1.K = TABLE(RKS1T, TIME.K, 0, 25, 5)$ EH9115
C $RKS1T =$ -VARIOUS PROGRAMS- EH9116

INVESTMENT FLOOR EQUATIONS FOR SECTOR 1 USED IN THE 3000 SERIES RUNS

28A $FRKS1.K = (NFS1)EXP(RFT1.K)$ EH9115
12A $RFT1.K = (RF1.K)(TIME.K)$ EH9116
59A $RF1.K = TABLE(RF1T, TIME.K, 0, 25, 2.5)$ EH9117

C RF1T*=.06/.06/.06/.08/.08/.09/.09/.10/.10/.10/.10
 C NFS1=.4

EH9118
 EH9119

RKS PROGRAM EQUATIONS FOR SECTOR 2 USED IN THE 2000 SERIES RUNS

59R RKS2.KL=TABLE(RKS2T,TIME.K,0,25,5)
 C RKS2T*=-VARIOUS PROGRAMS-

EH9200
 EH9201

RKS PROGRAM EQUATIONS FOR SECTOR 2 USED IN THE 3000 SERIES RUNS

59R RKS2.KL=TABLE(RKS2T,TIME.K,0,25,5)
 C RKS2T*=2.7/5.0/5.0/5.0/5.0/5.0

EH9200
 EH9201

INVESTMENT CEILING EQUATIONS FOR SECTOR 3

51R RKS3.KL=CLIP(RKSA3.K,0,RKSA3.K,0) KEEPS ACTUAL RKS POSITIVE
 51A RKSA3.K=CLIP(PRKS3.K,CRKS3.K,0,PROB3.K)
 51A PRKS3.K=CLIP(DRKS3.K,FRKS3.K,DRKS3.K,FRKS3.K)
 7A PROB3.K=PROB9.K+TRKS3.K
 51A TRKS3.K=CLIP(-4,0,CRKS3.K,PRKS3.K)
 7A CRKS3.K=CRKA3.K+RKP3.K
 46A CRKA3.K=(G3)(EINV3.K)(1)/((PK3.K)(UPSI3)(1))
 7A EINV3.K=CINV3.K-INV3.K
 43A CINV3.K=SAMPLE(PINV3.K,VARI9)
 12A PINV3.K=(INV3.K)(PC3)

EH9301
 EH9302
 EH9303
 EH9304
 EH9305
 EH9306
 EH9307
 EH9308
 EH9309
 EH9310

INITIAL CONDITIONS AND CONSTANTS

C PC3=0.90
 C UPSI3=.25

EH9311
 EH9312

NOTE THE FOLLOWING EQUATION REPLACES EH9301-EH9312 WHEN INVESTMENT
 NOTE CONTROLS ARE NOT USED IN SECTOR 3

51R RKS3.KL=CLIP(DRKS3.K,FRKS3.K,DRKS3.K,FRKS3.K)

EH9313

INVESTMENT FLOOR EQUATIONS FOR SECTOR 3 USED IN THE 2000 SERIES RUNS

59A FRKS3.K=TABLE(RKS3T,TIME.K,0,25,5) EH9315
 C RKS3T*= -VARIOUS PROGRAMS- EH9316

INVESTMENT FLOOR EQUATIONS FOR SECTOR 3 USED IN THE 3000 SERIES RUNS

28A FRKS3.K=(NFS3)EXP(RFT3.K) EH9315
 12A RFT3.K=(RF3.K)(TIME.K) EH9316
 59A RF3.K=TABLE(RF3T,TIME.K,0,25,2.5) EH9317

INITIAL CONDITIONS AND CONSTANTS

C RF3T*=.12/.12/.12/.10/.10/.10/.10/.10/.10/.10 EH9318
 C NFS3=.4 EH9319

RKS PROGRAM EQUATIONS FOR SECTOR 4 USED IN THE 2000 SERIES RUNS

59R RKS4.KL=TABLE(RKS4T,TIME.K,0,25,5) EH9400
 C RKS4T*= -VARIOUS PROGRAMS- EH9401

RKS PROGRAM EQUATIONS FOR SECTOR 4 USED IN THE 3000 SERIES RUNS

59R RKS4.KL=TABLE(RKS4T,TIME.K,0,25,5) EH9400
 C RKS4T*=0.25/1.0/1.5/1.5/1.0/0.5 EH9401

INVESTMENT CEILING EQUATIONS FOR SECTOR 5

51R RKS5.KL=CLIP(RKSA5.K,0,RKSA5.K,0) EH9501
 51A RKSA5.K=CLIP(PRKS5.K,CRKS5.K,0,PROB5.K) EH9502
 NOTE PRKS5 DEFINED IN EH5057 EH9503
 7A PROB5.K=PROB9.K+TRKS5.K EH9504

51A	TRKS5.K=CLIP(-4,0,CRKS5.K,PRKS5.K)	EH9505
7A	CRKS5.K=CRKA5.K+RKP5.JK	EH9506
46A	CRKA5.K=(G5)(EINV5.K)(1)/((PK5.K)(UPSI5)(1))	EH9507
7A	EINV5.K=CINV5.K-INV5.K	EH9508
43A	CINV5.K=SAMPLE(PINV5.K,VARI9)	EH9509
12A	PINV5.K=(INV5.K)(PC5)	EH9510

INITIAL CONDITIONS AND CONSTANTS

C	PC5=0.90	EH9511
C	UPSI5=0.25	EH9512

NOTE THE FOLLOWING EQUATION REPLACES EH9501-EH9512 WHEN INVESTMENT
 NOTE CONTROLS ARE NOT USED IN SECTOR 5

51R	RKS5.KL=CLIP(PRKS5.K,0,PRKS5.K,0)	EH9513
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WAGE CONTROL EQUATIONS FOR SECTOR 1

51A	RW1.K=CLIP(CRW1.K,DRWA1.K,RINF9.K,MANF1)	EH9124
12A	CRW1.K=(CW1)(CRWA1.K)	EH9125
51A	CRWA1.K=CLIP(DRWA1.K,CRWB1.K,RINF9.K,DRW1.K)	EH9126
12A	CRWB1.K=(W1.K)(RINF9.K)	EH9127
42A	DRW1.K=DRWA1.K/((WD1)(W1.K))	EH9128
7A	DRWA1.K=RWA1.K+WA1.K	EH9129

INITIAL CONDITIONS AND CONSTANTS

C	CW1=0	= 0 FOR CONSTANT W1 / = WD1 FOR RW1= COST OF LIVING	EH9130
C	MANF1=.02	= MANF FOR CONTROL OF W1 / = 1 FOR NO CONTROL OF W1	EH9131

WAGE CONTROL EQUATIONS FOR SECTOR 3

51A	RW3.K=CLIP(CRW3.K,DRWA3.K,RINF9.K,MANF3)	EH9324
12A	CRW3.K=(CW3)(CRWA3.K)	EH9325
51A	CRWA3.K=CLIP(DRWA3.K,CRWB3.K,RINF9.K,DRW3.K)	EH9326
12A	CRWB3.K=(W3.K)(RINF9.K)	EH9327
42A	DRW3.K=DRWA3.K/((WD3)(W3.K))	EH9328
7A	DRWA3.K=RWA3.K+WA3.K	EH9329

	INITIAL CONDITIONS AND CONSTANTS			
C	CW3=0	= 0 FOR CONSTANT W3 / = WD3 FOR RW3= COST OF LIVING		EH9330
C	MANF3=.02	= MANF FOR CONTROL OF W3 / = 1 FOR NO CONTROL OF W3		EH9331

VARIABLE TAX EQUATIONS

1L	VTAX.K=VTAX.J+(DT)(RTP.J+RTN.J)		EH9601
51A	RTP.K=CLIP(RTPA.K,0,RTPA.K,0)		EH9602
17A	RTPA.K=(NVTAX)(ROEIT)(RINF9.K)+(NVTAX)(ROEIT)(-MANF)+(1)(0)(0)		EH9603
51A	RTN.K=CLIP(RTNA.K,TAXDT.K,VTAX.K,0)		EH9604
51A	RTNA.K=CLIP(0,RTNB.K,RTNB.K,0)		EH9605
17A	RTNB.K=(NVTAX)(ROEDT)(RINF9.K)+(NVTAX)(ROEDT)(-.015)+(1)(0)(0)		EH9606
20A	TAXDT.K=-VTAX.K/DT		EH9607

	INITIAL CONDITIONS AND CONSTANTS			
6N	VTAX=0			EH9608
C	NVTAX=0	=1 FOR VARIABLE TAX / =0 FOR NO VARIABLE TAX		EH9609
C	ROEIT=1.0/ROEDT=.5			EH9610

DEVALUATION POLICY EQUATIONS

1L	XRD.K=XRD.J+(DT)(DELXR.J+0)	DEVALUATION POLICY EXCHANGE RATE	EH9701
51A	DELXR.K=CLIP(DELXA,0,CL7.K,WAIT7)	ADDS NEXT ENCREMENT TO XRD	EH9702
44A	DELXA.K=(XRD.K)(PCDEV)/DT	NEXT INCREMENT TO XRD	EH9703
1L	CL7.K=CL7.J+(DT)(DCL7.J+0)	A VARIABLE (CLOCK) THAT PROVIDES	EH9704
NOTE		A MINIMUM SPACING OF WAIT7 BETWEEN DEVALUATIONS.	EH9704
51A	DCL7.K=CLIP(CLR7.K,CLQ7.K,CL7.K,WAIT7)	RESETS CL7 TO 0 WHEN	EH9705
NOTE		CL7=WAIT7.	EH9705
20A	CLR7.K=-CL7.K/DT	DECREMENT FOR RESETTING CL7 TO ZERO	EH9706
51A	CLQ7.K=CLIP(CLP7.K,1,CL7.K,WATA7)	STOPS CL7 AT WATA7 IF NO PROB.	EH9707
51A	CLP7.K=CLIP(1,0,0,NFXR7.K)	STARTS CL7 IF PROB. EXISTS	EH9708
14A	NFXR7.K=FXR.K+(FXR7)(BPF.K)		EH9709
7N	WATA7=WAIT7-DT	INTERVAL BETWEEN THE TIME A FOREIGN EXCHANGE	EH9710
NOTE		CRISIS ARISES AND THE INDUCED DEVALUATION.	EH9710

	INITIAL CONDITIONS AND CONSTANTS	
6N	XRD=4.8	EH9711
7N	CL7=WAIT7-DT	EH9712
C	PCDEV=.2	EH9713
C	WAIT7=2.8/FXYR7=4.5	EH9714

TARIFF EQUATIONS USED IN THE 2000 SERIES RUNS

43A	T6.K=SAMPLE(TA6.K,0.5)	EH9740
1L	TA6.K=TA6.J+(DT)(RT6.JK+0)	EH9741
51R	RT6.KL=CLIP(RTD6.K,RTI6.K,VART6.K,0)	EH9742
12A	RTI6.K=(ROEI6.K)(-VART6.K)	EH9743
51A	RTD6.K=CLIP(RTDA6.K,TA6DT.K,TB6.K,0)	EH9744
12A	RTDA6.K=(ROED6)(-VART6.K)	EH9745
14A	TB6.K=TA6.K+(RTDA6.K)(DT)	EH9746
20A	TA6DT.K=TA6.K/DT	EH9747
12A	VART6.K=(TARIF)(BPF.K)	EH9748
43A	T7.K=SAMPLE(TA7.K,0.5)	EH9750
1L	TA7.K=TA7.J+(DT)(RT7.JK+0)	EH9751
51R	RT7.KL=CLIP(RTD7.K,RTI7.K,VART7.K,0)	EH9752
12A	RTI7.K=(ROEI7.K)(-VART7.K)	EH9753
51A	RTD7.K=CLIP(RTDA7.K,TA7DT.K,TB7.K,0)	EH9754
12A	RTDA7.K=(ROED7)(-VART7.K)	EH9755
14A	TB7.K=TA7.K+(RTDA7.K)(DT)	EH9756
20A	TA7DT.K=TA7.K/DT	EH9757
18A	VART7.K=(TARIF)(CAP3.K-1.4)	EH9758
12A	MAXP6.K=(2.0)(P1.JK)	EH9761
51A	ROEI6.K=CLIP(0,RHOI6,P6.JK,MAXP6.K)	EH9762
12A	MAXP7.K=(1.1)(P3.JK)	EH9763
20A	CAP3.K=QH3.K/KB3.K	EH9764
51A	ROEI7.K=CLIP(0,RHOI7,P7.JK,MAXP7.K)	EH9765

	INITIAL CONDITIONS AND CONSTANTS	
6N	TA6=.00	EH9749

6N	TA7=.00	EH9759
C	RHOI6=0.25/RHOI7=0.5/ROED6=0.1/ROED7=0.2	EH9760
C	TARIF=1.0 = 0 FOR NO TARIFF POLICY / = 1 FOR TARIFF POLICY	EH9766

TARIFF EQUATIONS FOR THE 3000 SERIES RUNS

	INITIAL CONDITIONS AND CONSTANTS	
1L	TT6.K=TT6.J+(DT)(DTT6.J+0)	EH9721
51A	DTT6.K=CLIP(DATT6.K,0,CL7.K,WAIT7)	EH9722
46A	DATT6.K=(TARIF)(PCTT6.K)(TT6.K)/((DT)(1)(1))	EH9723
1L	TT7.K=TT7.J+(DT)(DTT7.J+0)	EH9724
51A	DTT7.K=CLIP(DATT7.K,0,CL7.K,WAIT7)	EH9725
46A	DATT7.K=(TARIF)(PCTT7.K)(TT7.K)/((DT)(1)(1))	EH9726
7A	T6.K=TT6.K-1	EH9727
7A	T7.K=TT7.K-1	EH9728
12A	MAXP7.K=(1.1)(P3.JK)	EH9731
51A	PCTT7.K=CLIP(0,PCT7,P7.JK,MAXP7.K)	EH9732
12A	MAXP6.K=(2.0)(P1.JK)	EH9733
51A	PCTT6.K=CLIP(0,PCT6,P6.JK,MAXP6.K)	EH9734

	INITIAL CONDITIONS AND CONSTANTS	
6N	TT6=1	EH9729
6N	TT7=1	EH9730
C	PCT6=.00/PCT7=.20	EH9735
C	TARIF=1.0 = 0 FOR NO TARIFF POLICY / = 1 FOR TARIFF POLICY	EH9736

CONSUMERS FLEXIBLE EXCHANGE RATE USED IN THE MULTIPLE EXCHANGE RATE POLICY

1L	XRF.K=XRF.J+(DT)(RXRF.JK+0) FLEXIBLE EXCHANGE RATE	EH9715
15R	RXRF.KL=(-OMEG7)(NFXRF.K)+(-PSI7)(BPF.K)	EH9716
51A	NFXRF.K=CLIP(0,NFXR7.K,NFXR7.K,0) NEGATIVE VALUES ONLY OF NFXR7	EH9717

	INITIAL CONDITIONS AND CONSTANTS	
6N	XRF=4.8	EH9718
C	OMEG7=5.0	EH9719
C	PSI7=2.0	EH9720

QUOTA EQUATIONS FOR CONSUMER IMPORTS

1L	$MC6.K = MC6.J + (DT)(-DEM6.J + 0)$	CURRENT VALUE OF QUOTA	EH9770
51A	$DEM6.K = CLIP(DMC6A.K, 0, CL7.K, WAIT7)$	REDUCES QUOTA WHEN $CL7 = WAIT7$	EH9771
44A	$DMC6A.K = (MC6.K)(PCC6)/DT$	COMPUTES NEXT QUOTA REDUCTION	EH9772

INITIAL CONDITIONS AND CONSTANTS

6N	$MC6 = 2.1$		EH9773
C	$PCC6 = .20$		EH9774

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