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PLANNING FOR GROWTH

Multi-sectoral, Inter-temporal Models Applied to India

Richard S. Eckaus and Kirit S. Parikh

Volume I

Center for International Studies
Massachusetts Institute of Technology
April 1966

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Planning for Growth

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PREFACE

Scholarly books on economic development as well as the programs prepared by planning commissions frequently begin with admonitions that the development process is an intricate interaction of many economic, political and cultural factors. Scholars then proceed by simplifying assumptions to develop both general theories of the growth process and explanations of particular aspects. Practical planners also simplify the development process in making their plans for they, no more than academic scholars, fully understand the process or are successful in integrating their partial and incomplete insights. It is true that actual economic plans often treat many aspects of development and contain a great amount of detail. Even so, such plans are, for the most part, collections of separate programs whose real interactions are not fully worked out and taken into account in the making of policy. The inadequacies of the planning methods which are practiced are only partly due to the limitations of the development theories which are available and most development plans could be improved by a more consistent and intensive application of these theories. Moreover, the development of high speed computers made it possible to apply these theories more effectively. An awareness of the gap between the practice of economic planning and the potentially available tools was part of the inspiration of the project which led to this monograph.

The central issues of overall development policy and growth theory are the mobilization and optimum use of resources. These issues are analyzed here by means of linear programming models in which intersectoral and intertemporal relationships are made explicit. These models may be considered as extensions and applications of the multi-sectoral theories

of capital accumulation and growth and the one or two-sector models which are now current in growth theory. The models are elaborated in several versions. Each solution of the models, in maximizing the value of the objective function and meeting all the production and behavioral constraints which are imposed, determines all the necessary resource allocations including intersectoral flows and capital formation. The sensitivity of the results to errors in estimation and alternative policies are investigated by means of successive solutions with different values of parameters and exogenous quantities.

The models remain highly abstracted versions of a real economy in part because we have not exploited all the potential of modern growth theory and in part because that theory is still far from being realistic. Many of the complexities of economic growth such as external economies, changes in foreign trade specialization and induced innovation are still not effectively embodied in growth theory. Furthermore the information and computation which would be required to implement much of the theory place it beyond the possibility of immediate use. But there are aspects and versions of growth theory whose information requirements are hardly greater than those of the planning methods now being used. The computational requirements are great but still within the feasible range of high speed, digital computers.

While we have tried to construct a bridge between some areas of economic theory and economic policy we have not attempted to be either as comprehensive or as specific as required by the real tasks of planning. We believe, however, that even a modest version of the type of analysis presented can add important insights for economic policy beyond what has been available while not subtracting from whatever wisdom can be brought

to bear from other sources. Moreover, in concrete applications, the models can be both extended and made more specific depending on the information available, the detail desired and the computational capacity available.

The project on which this monograph is based provides, we believe, an example of the principle of critical minimum effort which operates in economic research organization as in physics and economic development. That critical minimum in this case was the support of several organizations and a large number of people for various periods. The project had its origins in the winter of 1961-62 in the individual and cooperative research of N. Andreatta, R.S. Eckaus and P. Sevaldson, then members of the India Project of the Center for International Studies, and S. Chakravarty, who had previously been a Research Associate of the Center, and was a consultant to the group. In this initial stage the adequacy of existing and potential sources of empirical information was established and alternative theoretical model structures were described. Dr. Ashish Chakravarti, then of the Indian Statistical Institute, gave invaluable advice on empirical problems in this early phase. Work on the project continued in 1962-63 both in New Delhi and in Cambridge, Mass. In India James Mirrlees and Per Sevaldson continued efforts to improve the empirical information and Sevaldson prepared a paper describing a linear programming model. In Cambridge Kirit Parikh assumed complete responsibility for computations and participated with R.S. Eckaus and Louis Lefeber, who joined the project, in data preparation and model formulation. In 1963-64 S. Chakravarty, who was then visiting the M.I.T. Department of Economics, resumed his association with the project. By the end of the 1963-64 academic year when Chakravarty and Lefeber left Cambridge most of the computations on the short-term Target and Transit Models for

the Indian Third Plan period had been completed. Subsequently Fabian and Parikh applied the models to the Fourth Plan period and developed and calculated the long term, Guidepost Models and the Guidepost Models.

In its early stages in particular, therefore, the [illegible] group effort to which a number of persons [illegible] those of Chakravarty and [illegible]

Jalael Ahmad, Michael [illegible], [illegible] T. Krishnan, Shri Raiss, [illegible] and [illegible] and gave critical help in [illegible] Great [illegible] manuscript.

The advice and encouragement of [illegible] ning Commission, [illegible] taking of the project [illegible] Ex and Mr. [illegible] continuing support.

The [illegible] of persons [illegible] and [illegible]

[illegible] and [illegible] values.

Support for the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

cooperative in providing computation facilities. Of course none of these organizations bears any responsibility for the analysis and opinions expressed here.

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CHAPTER 1

INTRODUCTION

A beggar to the graveyard hied
And there 'Friend corpse, arise,' he cried;
'One moment lift my heavy weight
Of poverty; for I of late
Grow weary, and desire instead
Your comfort: you are good and dead.'
The corpse was silent. He was sure
'Twas better to be dead than poor.

--The Panchatantra

1.1 Planning Models -- analytical tools

Economic policy requires a variety of analytical tools depending on the nature of the problems and the policy instruments which can be brought to bear. The purpose of this book is to describe several linear programming models for inter-temporal and inter-sectoral allocation of scarce resources and their application to development planning in India.

Linear programming models of capital accumulation and inter-sectoral resource allocation have become familiar tools of theoretical analysis[1] and have had a considerable amount of practical application.[2] The models presented below are analytical innovations only to the extent that they are structured to the requirements of development planning and the availability of data for a specific country. At best these models deal with only a few of the many issues involved in making economic policy. Moreover, the models are not finished products in the sense that they are ready to start producing complete development plans. This monograph should be considered as a report on a pilot project intended to demonstrate both the potentialities and the limitations of the method. In addition,

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1 Since other bibliographies of linear programming are available and its intellectual origins are well known (see G.B. Dantzig, Linear Programming and Extensions, Rand Corporation, August, 1963) we need only record our most immediate inspiration which has been R. Dorfman, P.A. Samuelson and R. Solow, Linear Programming and Economic Analysis. The models used are generalizations of that presented in R.S. Eckaus and L. Lefeber, "Capital Formation: A Theoretical and Empirical Analysis," Review of Economics and Statistics, XLIV, May 1962, pp. 113-122, but have been modified in many particulars by S. Chakravarty, L. Lefeber, and the authors and have benefited from the suggestions of others.

2 See, for example: H.B. Chenery and K.S. Kretchmer, "Resource Allocation for Economic Development," Econometrica, October 1956 and other articles by Chenery; J. Sandee, A Long Term Planning Model for India, Calcutta, 1960 and M. Bruno, Interdependence, Resources Use and Structural Change in Israel, Jerusalem, 1962.

we believe the analysis generates some new insights into the Indian economy.

Planning models as analytical tools provide methods of exercising foresight and making rational policies. In themselves the models do not imply any particular ideological outlook nor a commitment to a particular program of implementation. Their use is consistent with either considerable centralization or decentralization of decision-making and any mix of direct and indirect means of influencing production. Having an economic policy is inevitable and it would appear to be desirable to improve all types of analytical tools which might help in forming policy. The models presented here need no more justification than this.

In this chapter we shall first present a short description of the methods of Indian economic planning in order to provide a background for the subsequent application of the models. A review of the strengths and weaknesses of the models could perhaps best be left to the end of the book when they can be better appreciated. However, a brief synopsis of the approach will provide a frame of reference for what follows and forewarnings of pitfalls which must be avoided in using the models.

1.2 A Reconnaissance of Planning Techniques in India

The accomplishments of the Indian economy since independence in the face of an extraordinary number of all but overwhelming difficulties are remarkable in themselves and especially so in comparison with pre-independence conditions. India became independent in August, 1947. The First Five Year Plan of economic development was started in 1950-51 and was followed by the Second Five Year Plan in 1956-57 and the Third Five Year Plan in 1961-62.

This sustained effort toward economic development through consent rather than coercion is a tribute to the determination of the Indian political leadership and the Indian people. The achievements of this effort have been amply recorded as have been the failures.[1] Here we shall concentrate on describing the techniques of planning which have been used.

In the formation of economic policy in India a comprehensive set of social and economic goals have been articulated. These include immediate alleviation of poverty to some degree and achievement of a rate of growth which will provide for a substantially improved standard of living in the future. An increase in employment opportunities is regarded not only as a means of achieving these goals but also as an end in itself as is a less disparate distribution of income and greater equality of social and economic opportunities. Improved education, medical and other welfare facilities are also proposed in the Plans. These and other goals are to be achieved in the context of a free and socialist economy in which there will be a substantial role for private enterprise.

The Indian Plans, which are widely regarded as among the most sophisticated of the less developed areas, have provided the general framework for the evolution of the Indian economy. Internally they provide the output and investment targets on the basis of which investment and import licenses are granted to the private sector and new projects are started in the public sector. The national and the state plans are prepared at the same time and efforts are made to coordinate them. Externally the Plans have served as the basis for negotiation of foreign assistance,

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1 E.g., J.P. Lewis, Quiet Crisis in India.

While the Plans may be better regarded as statements of intent rather than rigid blueprints, they are the backbone of government economic policy.

The First Plan was, for the most part, a rather hastily organized program of government projects. The Second and Third Plans were the object of more intense preparation as is the case with the prospective Fourth Plan. The processes which generate the Plans cannot be entirely clear to outsiders and we shall draw on the Plans themselves for our summarization of techniques. The macroeconomic model of the Plan is described most clearly in the Second Five Year Plan document. It is a model of growth generated by capital accumulation based on domestic saving and foreign capital. The sources of domestic saving in the household, business and government sectors are analyzed separately in the more complete formulations.[1]

The strength of the Indian Plans is in their abundant detail of specific government sectors projects. These make up, in space allotted, by far the largest part of the Third Plan document. In addition, targets are set for sectors which are predominantly in private hands though for these sectors less detail is provided. However, careful plans are made for a wide variety of government activities designed to assist, stimulate or regulate private enterprise. For example, there are extensive programs of government activity in agriculture and in establishing industrial centers.

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1 The aggregate analyses implicit in the Third Plan are set out in I.M.D. Little, "Tax Policy and the Third Plan," in Pricing and Fiscal Policies, P.N. Rosenstein-Rodan, ed., Cambridge, 1964 and in S. Chakravarty, "The Mathematical Framework of the Third Five Year Plan," and P.N. Rosenstein-Rodan, "Alternative Numerical Models of the Third Five Year Plan of India," in Capital Formation and Economic Development, P.N. Rosenstein-Rodan, ed., Cambridge, 1964.

The sectoral targets are set by experts of the relevant economic ministries, the Planning Commission and Finance Ministry. These experts meet in inter-agency committees which overlap and pyramid in order to take sectoral interrelationships and aggregate objectives and limitations into account. These committees can bring a great deal of practical experience to bear on the problems of expanding capacity and output in each sector and in integrating the sectoral plans. The guidelines provided the committees appear to be based on comparative statics analysis of commodity balances and macroeconomic balances.

In working out the commodity balances the goals of the Plans are specified for the final Plan year. The projected supplies and demands of the major commodities for the final Plan year are brought into equality in an attempt to insure overall consistency. This balancing is most prominent in a preliminary analysis made for the Fourth Plan.[1] Demands are projected for private and government consumption, exports and domestic industrial requirements. The latter are calculated by means of "consumption norms" which, like the input-output ratios of inter-industry matrices, relate current input requirements to sectoral output levels. Supplies are computed based on existing capacity, imports and new investment which is converted into capacity estimates by means of capital-output ratios. Where there has been detailed advance planning for particular sectors such as steel production, investment requirements appear to be based on project plans. In the Fourth Plan preliminary analysis different capital-output coefficients have been used for new units and the expansion of existing

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1 Perspective Planning Division, Planning Commission, Notes on Perspective of Development, India: 1960-76, New Delhi, April, 1964.

units. In some sectors, such as agriculture and services, output has been projected by extrapolations for which no detailed explanations are available. Time trend extrapolation may also have been used for some components both in the sectoral and aggregate calculations.

The patterns of the Indian economy are still evolving, but it seems from the first three Five Year Plan periods that a 'mixed economy' is emerging. Some sectors such as rail transport and electric power have been entirely reserved for public enterprise and in other sectors, such as steel, coal and heavy machinery, public and private enterprise co-exist. The Indian government has attempted to guide the private sector by means of a variety of direct and indirect controls. Direct controls on investment and import licensing are pervasive. Output controls exist in some sectors and are supplemented by extensive price controls. There are also controls on the use of certain commodities in production. An extensive range of government activities from community development to government research laboratories provide assistance and leadership to the economy. In addition to its veto and control powers, the government through the purchases and sales of its public enterprises creates incentives for private enterprise to pursue the goals of the Plans. Private enterprise has not been forced where it does not want to go, however, and it has substantial freedom in the control of day-to-day activity. The vigorous private entrepreneurship evident in India is eloquent testimony to the opportunities which exist for the private sector.

The demands of private consumers are not controlled directly and both the public and private sectors respond to these private market generated stimuli. Consumer demands create a set of incentives which are not necessarily consistent with those required to achieve the targets

established in the Plans. However, both fiscal and monetary policy have been used extensively in attempts to bring privately generated demands into consistency with Plan objectives. This is seen in the relatively high marginal savings rates, achieved to a large extent through continuing increases in the scope and level of indirect taxes. These fiscal measures must be given credit for keeping the changes in price levels to relatively modest proportions until recent years.

There has been intensive debate over the Plans in India. The newspapers and journals of opinion reflect this debate within the government before the Plans are made public and the debate continues in the national arena afterward. The debate, which itself constitutes consideration of alternatives, focuses on the size of the plan and the relative emphasis to be placed on the various sectors. Unfortunately the debate has not been well informed with respect to the relationships among these issues and with respect to the intertemporal distribution of benefits. The view appears to have been generally accepted that the bigger the Plans are the better they are and the controversy has focused on the feasibility of certain levels of domestic saving and investment and the requirements for foreign aid.

Plan making must include consideration of both ends and means and it should produce a compatible program. In formulating the ends of economic policy, broadly phrased ideals and declaration of objectives have to be made quantitatively specific. They must have numbers attached to them. 'Some degree of immediate alleviation of poverty and future improvement in the standard of living' can encompass any number of different intertemporal patterns of present and future income. Without careful testing the feasible

range of alternatives cannot be established. Policy makers cannot be expected either to be able to generate detailed goals or even to realize what specific alternatives are open to them. It is the task of the planning technicians to prepare explicit quantitative alternative plans which provide policy makers with an informed basis for choice. In India the process of particularizing economic goals has not been clear and straightforward. In this deficiency it should be quickly pointed out, Indian planning is not unique. The evidence available suggests that the investigations of alternatives which have been done in India have been both in the most highly aggregated type of macro-economic calculations and at the other extreme in the choice of particular projects. Though there is evidence of concern with the issues no techniques of relating aggregate and sectoral growth paths are evident in the Plans. The well-known analyses of two and four sector models by Professor Mahalanobis did try to provide a rationale for sectoral allocations.[1] It is difficult for an outsider to assess their influence in shaping the Indian Plans. Professor Mahalanobis' analyses seemed to justify a relative emphasis on the capital goods producing sectors but did not provide any precise guidelines. Moreover, the limitations of the analysis would prevent it from providing reliable indications.[2]

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1 "The Approach of Operational Research to Planning in India" and "Draft Plan Frame for the Second Five Year Plan," Sankhya, Vol. XVI, Dec. 1955, pp. 3-89.

2 For major criticisms see: S. Tsuru, "Some Theoretical Doubts on India's Plan Frame," Economic Weekly (Annual Number), Vol. V, January 1957; S. Chakravarty, The Logic of Investment Planning, pp. 43-48; R. Komiya, "A Note on Prof. Mahalanobis' Model of Indian Economic Planning," The Review of Economics and Statistics, Vol. XLI, Feb., 1959, pp. 29-35.

Finally, a brief note on the performance of the Indian economy in relation to the Plans: The First Plan was generally considered to be a success. Roughly speaking the output levels projected were achieved in most sectors. Major projects were started and, while they did not progress as rapidly as programmed, the Plan as a whole was believed to have gone well. Since the First Plan, while there have been great accomplishments, these have not measured up to what was projected. As compared to the Second and Third Plans' targets there have, with some exceptions, been general shortfalls in both the agricultural and industrial sectors. Furthermore, in both the Second and the Third Five Year Plan periods there were major foreign exchange crises due, in part, to special circumstances in each case. In the Third Five Year Plan period, in particular, the Chinese invasion, the military engagements with Pakistan and unfavorable agricultural conditions have placed special burdens on the Indian economy and its foreign exchange position. In general it has been assumed that the targets were, in fact, feasible. The reasons given for lack of success include not only the unforeseeable exigencies of weather and increased defense spending but also inadequacies in implementation which may mean either too little or too much or the wrong kind of government intervention depending on the source of criticism.

1.3 A Brief Description of the Models

Having described briefly the practice of Indian planning, we turn now to a brief survey of the models which will be presented in the following chapters. The present description is intended only to provide an overall view of the more detailed presentation of the following chapters.

The models are addressed to the problems of determining the optimal level of savings and investment over time, and the related intertemporal and intersectoral distribution of investment and output and the use of foreign exchange resources. They are linear programming models which are adapted in various ways in specific applications. There is a basic structure common to all of them. Production processes in all sectors require fixed capital and intermediate inputs in fixed proportions and have constant returns to scale. Many sectors need imports in fixed proportions as inputs. Imports are also permitted in varying amounts in certain sectors to supplement domestic production. A balance of payment constraint must be met each period. Private consumption is a composite commodity and is consumed in proportions which are fixed in each period. Furthermore aggregate consumption must increase monotonically with time. Investments for creating new capacity have to be made up to three years in advance. In any period stocks of inventories depend on the output of next period. Fixed capital and foreign exchange are the only scarce factors. Labor supply is unlimited. The economy is defined by the following elements:

(1) The objective or criterion function which is maximized is the sum of aggregate consumption in each of the plan periods discounted by a social discount rate. The solution of the models achieves the highest value of this function which is consistent with all the constraints. It should be noted, however, that in a programming model goals of economic policy can be stipulated not only by what is chosen to be maximized but also by the content of the constraints.

(2) A consumption growth constraint, for example, requires that aggregate consumption grow at a stipulated rate. This rate when compared to the population growth rate indicates a required rate of growth in the average standard of living.

(3) A savings constraint which is enforced in some of the models and which relates the level of net savings and net national product is another way of introducing social goals and a behavioral constraint into the models.

(4) Consumption proportions are specified exogenously or may be varied endogenously by means of consumption-expenditure elasticities.

(5) Distribution relations require that the total demand for each commodity in each period not exceed its availability in the period. The total demand consists of the requirements for the good as an intermediate input, which is determined by use of an input-output matrix and a number of final demands. These include the demand for inventories, the demand for new fixed investment purposes, the demand for replacement investment, public and private consumption and exports. The availability is the sum of domestic production and imports.

(6) Capacity restraints ensure by means of capital-output ratios that output of each sector in each period does not exceed that producible with the fixed capacity available in the sector at the beginning of that period.

(7) Capital accounting relationships determine capacity at the beginning of each period as the capacity previously available less depreciation plus the new, completed additions to capacity plus that part of the depreciated capacity which is restored.

(8) New capital creation takes place in each sector with a separate gestation lag for the contribution from each capital goods producing sector as specified by means of capital proportions matrices.

(9) Inventory requirements are determined by inventory-output matrices.

(10) Exports and public consumption are estimated exogenously.

(11) Imports are divided into two categories. "Non-competitive" imports are determined by exogenously specified import-output ratios which may, however, change over time. "Competitive" imports are allocated by the model with limits set, in some versions, on the extent to which this type of import can be absorbed in any one sector.

(12) Balance of payments constraints require that total imports in each period not exceed the foreign exchange availability as determined by exports and the stipulated net foreign capital inflow.

(13) The initial conditions are estimates of the productive capacity, stocks of inventories and unfinished capital-in-process

actually available at the beginning of the plan periods.

(14) Terminal conditions must be provided in some manner in order to relate the events of the plan period to the post plan period so the model will not behave as if time stopped at the end of the plan. These terminal conditions are either completely specified exogenously or partially derived endogenously depending on the purpose of the model.

This basic structure is combined in various ways and over different planning periods to develop a number of types of models which illustrate different points and analyze different problems. Although only eleven sectors are distinguished in the solutions, there is in principle, no barrier to greater sectoral detail, and some experiments were made at an eighteen sector level of disaggregation.

In the Target Model the terminal conditions are taken from targets for the Third and Fourth Indian Five Year Plans.[1] The model finds the maximum amount of consumption which can be produced within the plan period consistent with these targets and the other constraints. It also makes an exhaustive calculation of the total amount of investment and domestic savings required by the targets as well as the sectoral requirements in each year. By comparing these results with the planned allocations a test is provided of the overall feasibility and sectoral consistency of the Plans.

The Transit Model is also a five year model in which terminal conditions are set endogenously from a specification of required post-terminal

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1 The Fourth Five Year Plan has been postponed. All the references to the Fourth Plan in this book refer to the originally scheduled Fourth Plan period from 1966-67 through 1970-71.

sectoral growth rates. The model solution is an optimal transition, in terms of the objective function, to those growth rates. The Transit Model is an open-ended system as compared to the Target Model in which both, the initial as well as the terminal conditions are completely specified.

The Guidepath Models cover a span of eighteen or thirty years in alternative forms in successive periods of three years. This permits the treatment of those issues which require a long planning horizon for a comprehensive analysis. The Guidepath Models also embody techniques for endogenously changing consumption proportions and the shifting from use of "traditional" to "modern" techniques in the important agricultural sector. The Guidepath-I and Guidepath-II versions differ in that an explicit savings constraint is enforced in the latter model.

The Guidepost Model is a short term model and is used to obtain year by year detail for the early years of a long term path obtained from a solution of the Guidepath Model. It has periods of one year each but otherwise it has the structure of the Guidepath Models. The terminal targets, however, are obtained from the particular Guidepath solution and are specified in the manner of the Target Model.

Each of the models is solved for a variety of alternative specifications of behavioral, technical and policy parameters to determine the sensitivity of the results to changes in such parameters and to illustrate the range of policies which the models can analyze. Each solution of a model generates for each sector and each period all the uses of capacity, foreign exchange and output which are consistent with the maximum value of the objective function and the constraints. Period-by-period detail national income accounts are compiled to show the overall workings of the economy. In

addition the solution provides a set of shadow prices corresponding to the various constraints which indicate the value, in terms of the maximand, of a marginal adjustment in the constraint. The shadow prices are analogues of the prices of the real world but must be interpreted with care as they reflect rigorously the particular structure of the model.

1.4 Preliminary Evaluation of the Models' Structure

Many of the inadequacies of the planning models to be presented must already be obvious and others will become apparent as the detailed presentation proceeds. Though final evaluation must wait until the last chapter a brief survey of the limitations of the approach will help put the unwary reader on guard and aid in understanding the character of the results.

Although economic planning in practice has many different goals, consumption is the only criterion in the objective function of the models. Some additional social goals are introduced and still others could be introduced as linear constraints. The linearity of the objective function, i.e., the assumption of a constant marginal utility of consumption is a serious limitation as it has a major influence on the intertemporal distribution of consumption and investment. Yet, though the objective function is linear, the constraints which specify a minimum consumption growth rate and those which relate savings and net national product have an effect on the solution similar to non-linearities in the objective function. With suitable specification of these constraints any desired time path of consumption which is feasible can be obtained. We believe that the present formulation has the advantage that the significance of the constraints is more readily apparent and meaningful to planners than is the slope of a social consumption-utility function.

Another limitation of the models is in the way sectoral consumption is determined in exogenously fixed proportions or in proportions determined by fixed elasticity relations with total consumption. No opportunity is provided for relative variations depending on price elasticities. The only means of adjusting sectoral demands for consumption thus becomes that of changing total consumption. As a result bottleneck situations in a particular sector can have the effect of constraining overall consumption. This is particularly important in short run models; over longer periods the models will "foresee" and avoid such situations. On the other hand, the high degree of aggregation in these models makes substitution less important and in a practical application on a more disaggregated basis some amount of flexibility can be permitted with additional computational costs.

In these models the only scarce factors are capital stocks and foreign exchange whereas labor is assumed to be free. Even though a gestation period for capital is specified and government expenditures provide for education these devices cannot take into account fully the problems of developing raw material supplies, of training labor and developing managerial skills. It would be possible to expand the models to take into account other scarce factors, for example, to require various types of labor inputs for production and to specify the methods of their supply in models of this type. These additional production relationships were not introduced in the present analyses for several reasons. First of all, they would increase the computational requirements substantially. Secondly, there is relatively little data available on the types of labor skills required in the different sectors and even less information on how these skills are acquired in the Indian economy. Moreover general considerations suggest that the types of expertise

which are most likely to be bottlenecks, i.e. those of foremen and managers, are most difficult to quantify.

The production functions in the models are homogenous of the first degree, i.e. show absolutely constant returns to scale, and have fixed input-coefficients so that there is no provision for increasing or decreasing returns to scale, substitution of relatively scarce factors or increasing productivity by learning-by-doing. In addition all production relations are accounted for directly in inputs and outputs so there are no external economies or diseconomies. These are extreme assumptions for a development model and cannot be justified but are used for lack of data to do otherwise. At the high level of aggregation of eleven sectors substitution among the outputs of different sectors may be unimportant but changes in the returns to scale which, with one exception, are not permitted, could be significant. The exception is in the agricultural sector in the Guidepath and Guidepost versions of the planning model. In a practical application a variation of the technique used in the agricultural sector could be used to simulate diminishing returns in other sectors. The externalities which are neglected in this approach are technological. The explicit accounting of inter-industry interdependences in the models represents a satisfactory treatment of the so-called pecuniary externalities.

In view of the importance given to changing techniques and externalities in the growth of less developed areas, a special comment is required on our inadequacies in these respects. The defense is essentially that changes in coefficients which can be dated or associated with particular projects can be embodied. If, in partial analyses of individual projects, technologies with different input-output proportions are chosen, sufficient

disaggregation would make it possible to respect the differences to some extent.[1] Since this model operates with a very few sectors it is necessary to examine the results carefully to arrive at a judgment as to what extent they are sensitive to the changes in technical coefficients which might be reasonably expected. The gestation periods for capital are also described by fixed lags when, in reality, there is some degree of variability depending in part on the relative urgency with which the capital is desired and the availability of capacity in the capital creating sectors.

The form of the inventory function is overly simple and again the coefficients are fixed. Depreciation is exogenous to the model and not a function of the intensity of use of capital. To some extent these relationships could also be improved in a full-scale effort.

The treatment of the foreign trade sector is also too simple. In particular no endogenous procedure is provided for changing the import requirements with the development of domestic capacity. In addition the sectoral aggregation is too gross to provide a detailed basis for analyzing import substitution problems.

An issue which is frequently raised in connection with the use of programming models for development is whether the information available in the less-developed countries is sufficient in quantity and quality to justify the use of the techniques. The answer is surely different for different countries and few generalizations on this issue are possible. However, the view of economic conditions in less-developed areas as unmapped and unexplorable

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1 Developments in integer programming techniques which can be adapted to handle increasing returns are promising as are experiments with iterative procedures of various sorts combining integer and conventional linear programming.

terra incognita is unwarranted. There are some enclaves, the "modern sectors" usually, which may be relatively well-known even as compared to the more advanced countries, simply because of their size and newness. Sectors which have been major sources of exports have often been studied intensively in less-developed areas because of their importance as foreign exchange earners. Consequently considerable input-output and other data may exist even if the productive units are small and "unorganized."

In India and some other countries, the extensive systems of controls and public enterprise generate a substantial amount of useful information. Investment and import license applications frequently require supporting documents which list production information which will be used in making decisions. In addition, there may be price control procedures such as those of the Indian Tariff Commission which produce valuable data. For some commodities there are direct controls on use which generate a mass of detail in the various applications. In India a substantial bureaucracy has developed to administer these controls and regulations. Though the degree and ease of contact with private industry varies, a system of regular reports has helped to create a cadre of well-informed persons. In addition there have been industrial censuses in India, the most recent of which is for 1960, and a number of sample surveys. There are grave problems of compatibility of the census and survey material but they are valuable data sources.

Large areas remain which are nearly blank in terms of statistical information, especially the mass of agriculture and the handicraft and service sectors which are only partially and loosely tied to markets. These sectors, as is the case in India, are often among the largest in terms of output in underdeveloped countries, so the information inadequacies are serious.

In the models presented here all sectors are treated as if data of equal quality were available. This was done partly to develop a general technique and partly because the significance of errors in specification could be explored by testing the sensitivity of the solutions to changes in parameters, but mainly because of ignorances about the reliability of data.

It might, however, be noted that less formal planning procedures often make no smaller claims for data if they are to be used for the same purposes as the models presented here. On the other hand it is possible to use the models flexibly and integrate less formal procedures for some sectors with the more rigorous procedures for other sectors.

Given the major drawbacks which have been described what then can be the justification of the models? It is we believe simply that no other method of which we know does as well in providing a consistent analysis of inter-temporal and intersectoral relationships and economic goals. Whatever the means of implementation, decisions will have to be made of whether to start another steel plant next year, or build more power facilities or allocate foreign exchange to importing mining equipment, and so on. These decisions should be coordinated with all the sectoral development plans and the national goals. We believe the models indicate how this can be done in a manner which is an improvement over existing techniques.

Moreover, there are likely to be some important by-products associated with the techniques presented here. First of all, they make the issues involved in planning more explicit than do informal and partial techniques. For example, the problems involved in setting plan targets may be glossed over in using comparative statics analyses, e.g. commodity balances, because these methods do not force an explicit and thorough consideration of the issues

Secondly, the models inspire the development of data which might otherwise be ignored. Finally, the models suggest the usefulness of exploring alternatives and the design of planning methods for high-speed computation. Rather than, as has generally been the case, concentrating on the preparation of only a single plan, it becomes possible to trace the outlines of a number of alternative plans. In economic policy as in other areas, informed choices can be made only when the alternatives are known. These techniques make possible a substantial increase in informed knowledge about alternatives.

The misapprehension identified with the view that "plans cannot be made by punching a button on a computer" can also be discussed at this point in order to clarify the manner in which formal planning techniques should be used. First of all, it must be recognized that planning is a continuous process even though it has usually been explicitly organized in discrete and intensive phases every four to seven years. The quinquennial debates should not be allowed to obscure the reality of continuous adjustment and readjustment of means and ends which should and does go on. Similarly, the programming models of this book and other similar models should be considered as tools which should be used continuously in a variety of forms designed expressly to analyze particular problems. The use of high speed computers by these models is both a necessity and a virtue because it can produce with greater speed than otherwise possible and in much greater detail a range of alternative policies whose implications are developed in great detail. Finally, however, models will always be simplifications of reality, and not all the relevant considerations can be embodied in a computer program.

In a practical application the limits of computational cost which have been a constraint to the enlargement of the scope of this project would

be much less important. Even so there is no question of the next Five Year Plan for India or any other country rolling off the computer intact. Though the use of the computer can provide much more detailed information about alternative policies than has been available, the choice of any one is always up to the policy maker.

1.5 Outline of Chapters

The order of presentation will be as follows: In Chapter Two the structure of the models will be described as well as some of the reasons for choosing the particular relationships which are used. In Chapter Three the data used in implementing the models, their sources and the adjustments performed on them will be discussed. The use of the programming models for short term planning will be demonstrated in Chapter Four with tests of the Indian Third and Fourth Five Year Plans. In Chapter Five the Guidepath and Guidepost models will be presented and alternative long term growth paths generated. Chapter Six will be a brief summary and evaluation of the methods and results.

CHAPTER 2

THE TARGET MODEL AND THE TRANSIT MODEL

Since verbal science has no final end,
Since life is short, and obstacles impend,
Let central facts be picked and firmly fixed,
As swans extract the milk with water mixed.

--The Panchtantra

Since the general methods of linear programming are well known, the description of the models' analytic framework can be relatively brief with attention concentrated on issues related to the particular applications. First the structure which is common to both the models is presented and discussed. This consists of the behavioral and structural constraints and is called the Basic Model. Then the terminal conditions which distinguish each of the specific models are described. Finally a general appraisal is made of the analytical formulation of the models and of alternative formulations.

Table 2-1 presents a list of symbols which are used. The meanings of the symbols are repeated when they are first used. Capital letters are used for variables and small letters are used for parameters.

2.1 The Basic Model

The Basic Model defines an economy with the following characteristics:

(1) Production processes in all sectors require fixed capital and intermediate inputs in exogenously specified fixed proportions to output and have constant returns to scale.

(2) Most sectors require imports in exogenously fixed proportions to output.

(3) Additional imports are also permitted in certain sectors to supplement domestic production in amounts determined endogenously within specified ceilings.

Table 2-1

List of Symbols

List of Variables and Parameters[1]		Dimensions for n sectors, k activities T periods
A(t)	- net foreign capital inflow in period t	T
a(t)	- matrix of inter-industry current flow coefficients appropriate to period t	n x k
b(t)	- diagonal matrix of capital-output ratios	k x k
c(t)	- column vector, each term of which indicates the proportion of the sector's output in total consumption	n
C(t)	- aggregate consumption in each period	T
D(t)	- a vector of the amount of fixed capital (components) in each sector which is completely depreciated in period t	k
d	- a diagonal matrix which transforms depreciation into capacity immobilized, each of whose terms d_{jj} is the maximum of $\left(\frac{r_{1j}}{p_{1j}}, \frac{r_{2j}}{p_{2j}}, \ldots, \frac{r_{nj}}{p_{nj}}\right)$; (the r's and p's are explained below)	k x k
E(t)	- a column vector of exports by each sector	n
F(t)	- a column vector of deliveries by each sector for private consumption purposes	n
G(t)	- a column vector of deliveries by each sector for government consumption	n
H(t)	- column vector of deliveries by each sector for inventory accumulation	n
I	- identity matrix	n x n or k x k

1 Variables - capital letters
Parameters - small letters

Table 2-1 (continued)

List of Variables and Parameters[1]		Dimensions for n sectors, k activities T periods
$J(t)$	- column vector of deliveries of intermediate inputs by each sector	n
$K(t)$	- column vector of fixed capital capacity in each sector	k
$M(t)$	- column vector of total imports	n
$M'(t)$	- column vector of "non competitive" imports	k
m'	- diagonal matrix of import coefficients relating non-competitive imports to sectoral output	k x k
$M''(t)$	- column vector of "competitive" imports	n
m''	- column vector of coefficients indicating in each sector maximum use of the foreign exchange available after competitive import requirements have been satisfied	n
n	- number of sectors	
$N(t)$	- column vector of deliveries by each sector of investment goods for new capital formation	
p', p'', p'''	- investment lag proportion matrices for capital. The elements p'_{ij}, p''_{ij} and p'''_{ij} indicate the proportions of fixed capital in sector j supplied by sector i for new capacity 1, 2, or 3 periods ahead, respectively	n x k
p	- capital composition matrix each element of which is the sum $\sum_k p^k_{ij}$, and $\sum_i p_{ij} = 1.0$	n x k
$Q(t)$	- column vector of deliveries by each sector to restore depreciated capacity	n

Table 2-1 (continued)

List of Variables and Parameters[1]		Dimension for n sectors, k activities T periods
q_η	$[I-a(T)-(b(T)p'(T)+S(T)\eta-b(T)p''(T)(1+\eta)\eta$ $-b(T)p'''(T)(1+\eta)^2\eta]$ for $\eta = \beta, \delta, \gamma, \varepsilon$ or μ	n x n
R(t)	- a vector of depreciated capital capacities which are restored	k
r', r'', r'''	- matrices of coefficients each of which indicates the proportion of depreciated capacity in each sector j supplied by the sector i for restored capacity in period t-1, t-2, or t-3, respectively, to become effective in period t	n x k
r	- depreciation composition matrix each element of which is D_{ij}/D_j, where D_{ij} is the ith type of capital depreciated in sector j	n x k
s	- matrix of inventory coefficients each of element s_{ij} of which indicates the deliveries for inventory purposes by sector i to sector j per unit of additional output in sector j	n x k
T	- length of the plan in periods	
t	- time, in periods	
u	- unit row vector [1, 1, 1, ..., 1]	1 x n
V(t)	- a column vector of capacities which are lost in each sector due to the depreciation of some component of its capital stock	k
W	- value of the objective function which is equal to the present discounted value of aggregate consumption over the plan period	1
w	- social discount rate applied to aggregate private consumption	1
X(t)	- column vector of gross domestic outputs	k
Z(t)	- column vector of new additions to fixed capital capacity in each sector	k
$\emptyset$	- post-terminal growth rate for consumption	1
δ	- post-terminal growth rate for depreciation	1

Table 2-1 (continued)

List of Variables and Parameters[1]		Dimensions for n sectors, k activities T periods
γ	- post-terminal growth rate for government	1
ϵ	- post-terminal growth rate for exports	1
μ	- post-terminal growth rate for imports	1
$\rho(t)$	- minimum rate of growth of aggregate consumption $C(t)$ over $C(t-1)$	T
α_0	- diagonal matrix of growth rates used in calculating inventory investment in first period and maximum new investment in second and third periods	k x k
α_T $\alpha(5)$	- diagonal matrix of growth rates used in calculating terminal capital requirements	

(4) A balance of payments constraint must be met in each period which limits total imports to the total amount of exports and net foreign capital inflow in that period.

(5) Private consumption is a composite commodity whose sectoral proportions are fixed exogenously. Furthermore, consumption is required to increase monotonically in successive periods at specified rates.

(6) In order to create new capacity investment has to be made in the periods immediately preceding that in which the new capacity becomes available as determined by a fixed gestation process which varies among sectors but can be as long as three periods.

(7) In each period investment in inventories in each sector is linearly related to the change in output to be realized in the next period.

(8) Fixed capital stocks and foreign exchange are the only scarce factors. Labor and raw materials are assumed to be adequate and exogenous to the models.

Table 2-2 sets out all the relationships of the Basic Model and the terminal conditions for the Target and the Transit Models. They will be taken up one by one in the text.

Table 2.2

The Target and the Transit Models

(1) Objective function

(1.0) Maximize $W = \sum_{t=1}^{T} \frac{C(t)}{(1+w)^{t-1}}$

Subject to:

(2) Consumption growth constraints

(2.0) $C(t+1) \geq (1+\rho(t))C(t)$, for $t=0, \ldots, T-1$,

(2.1) Initial consumption

$C(0) = \overline{C(0)}$,

(3) Distribution relations

(3.0) $J(t)+H(t)+N(t)+Q(t)+F(t)+G(t)+E(t) \leq M(t)+X(t)$, for $t=1, \ldots, T$,

(3.1) Intermediate products

$J(t) = a(t)X(t)$, for $t=1, \ldots, T$,

(3.2) Inventory requirements

(3.20) $H(t) = s(t)\{X(t+1)-X(t)\}$, for $t=2, \ldots, T$,

(3.21) $H(1) = s(1)\{X(2)-(1+\rho_s)\overline{X(0)}\}$, for $t=1$,

(3.3) Private consumption

$F(t) = c(t)C(t)$, for $t=1, \ldots, T$,

(3.4) Government consumption

$G(t) = \overline{G(t)}$, for $t=1, \ldots, T$,

(3.5) Exports

$E(t) = \overline{E(t)}$, for $t=1, \ldots, T$,

(4) Capacity restraints

(4.0) $b(t)X(t) \leq K(t)$, for $t=1, \ldots, T$,

Table 2-2 (continued)

(5) Capital accounting relationships

(5.0) Investment requirements

$N(t) = p'Z(t+1) + p''Z(t+2) + p'''Z(t+3)$, for $t=1, \ldots, T$,

(5.1) Depreciated capital

$D(t) = \overline{D(t)}$, for $t=2, \ldots, T+3$,

(5.2) Depreciated capacity

$V(t) = dD(t)$, for $t=2, \ldots, T+3$,

(5.3) Restoration requirements

$Q(t) = r'd^{-1}R(t) + r''d^{-1}R(t+1) + r'''d^{-1}R(t+2)$, for $t=1, \ldots, T$,

(5.4) Capital accounting

$K(t+1) \leq K(t) + Z(t+1) + R(t+1) - V(t+1)$, for $t=1, \ldots, T+2$,

(6) Restoration ceilings

(6.0) $R(t) \leq V(t)$, for $t=2, \ldots, T+3$,

(7) Balance of payments constraints

(7.0) $uM(t) \leq \overline{A(t)} + uF(t)$, for $t=1, \ldots, T$,

(8) Imports

(8.0) Import composition

$M(t) = M'(t) + M''(t)$, for $t=1, \ldots, T$,

(8.1) Non-competitive imports

$M'(t) = m'(t)X(t)$, for $t=1, \ldots, T$,

(8.2) Competitive import ceilings

$M''(t) \leq m''(t)[\overline{A(t)} + uE(t) - uM'(t)]$, for $t=1, \ldots, T$,

Table 2-2 (continued)

(9) Initial capital in process restraints

(9.0) $K(1) = b(1)(1+\alpha_0)\overline{X(0)}$,

(9.10) $Z(2) + R(2) \leq \alpha_0 K(1) + V(2)$,

(9.11) $Z(3) + R(3) \leq \alpha_0(1+\alpha_0)K(1) + V(3)$,

(10) Terminal requirements in general

(10.01) $K(T+1) \geq \overline{K(T+1)}$,

(10.02) $K(T+2) \geq \overline{K(T+2)}$,

(10.03) $K(T+3) \geq \overline{K(T+3)}$,

(10.1) $s(T)X(T+1) \geq \overline{X_c(T+1)}$.

(11) 'TARGET MODEL' specification of terminal requirements:

Terminal capital stocks

(11.01) $K(T+1) \geq b(T)(1+\alpha_T)\overline{X(T)}$,

(11.02) $K(T+2) \geq b(T)(1+\alpha_T)^2\overline{X(T)}$,

(11.03) $K(T+3) \geq b(T)(1+\alpha_T)^3\overline{X(T)}$,

Terminal inventories

(11.1) $s(T)X(T+1) \geq s(T)(1+\alpha_T)\overline{X(T)}$.

(12) 'TRANSIT MODEL' specification of terminal requirements:

Post-terminal growth rates of demands and imports

$$\left.\begin{array}{ll}
(12.01)\ F(t) = F(T)(1+\phi)^{t-T}, & \\
(12.02)\ G(t) = \overline{G(T)}(1+\gamma)^{t-T}, & \\
(12.03)\ E(t) = \overline{E(T)}(1+\epsilon)^{t-T}, & \\
(12.04)\ D(t) = \overline{D(T)}(1+\delta)^{t-T}, & \\
(12.05)\ M(t) = M(T)(1+\mu)^{t-T}, &
\end{array}\right\} \quad \text{for } t > T$$

which implies

Table 2-2 (continued)

$$(12.1)\quad X(t) = a(T)X(t) + (s(T) + b(T)p')[X(t+1)-X(t)] + b(T)p''[X(t+2)-X(t+1)] + b(T)p'''[X(t+3)-X(t+2)] + F(T)(1+\emptyset)^{t-T} + \overline{G(T)}(1+\gamma)^{t-T} + \overline{E(T)}(1+\epsilon)^{t-T} + \overline{D(T)}(1+\delta)^{t-T} - M(T)(1+\mu)^{t-T}, \qquad \text{for } t > T.$$

Solution of (12.1)

$$(13.0)\quad X(t) = [I-a(T)-(b(T)p'+s(T))\emptyset-b(T)p''(1+\emptyset)\emptyset-b(T)p'''(1+\emptyset)^2\emptyset]^{-1}F(T)(1+\emptyset)^{t-T} + [I-a(T)-(b(T)p'+s(T))\gamma-b(T)p''(1+\gamma)\gamma-b(T)p'''(1+\gamma)^2\gamma]^{-1}\overline{G(T)}(1+\gamma)^{t-T} + [I-a(T)-(b(T)p'+s(T))\epsilon-b(T)p''(1+\epsilon)\epsilon-b(T)p'''(1+\epsilon)^2\epsilon]^{-1}\overline{E(T)}(1+\epsilon)^{t-T} + [I-a(T)-(b(T)p'+s(T))\delta-b(T)p''(1+\delta)\delta-b(T)p'''(1+\delta)^2\delta]^{-1}\overline{D(T)}(1+\delta)^{t-T} - [I-a(T)-(b(T)p'+s(T))\mu-b(T)p''(1+\mu)\mu-b(T)p'''(1+\mu)^2\mu]^{-1}M(T)(1+\mu)^{t-T},$$

for $t=T+1,\ T+2,\ T+3$.

Define

$$q_\eta \equiv [I-a(T)-(b(T)p'+s(T))\eta-b(T)p''(1+\eta)\eta-b(T)p'''(1+\eta)^2\eta],$$

for $\eta = \emptyset, \gamma, \epsilon, \delta, \mu$.

Then from (13.0),

Terminal capital stocks:

$$(14.0)\quad K(t) \geq b(T)q_\emptyset^{-1}F(T)(1+\emptyset)^{t-T} + b(T)q_\gamma^{-1}\overline{G(T)}(1+\gamma)^{t-T} + b(T)q_\epsilon^{-1}\overline{E(T)}(1+\epsilon)^{t-T} + b(T)q_\delta^{-1}\overline{D(T)}(1+\delta)^{t-T} - b(T)q_\mu^{-1}M(T)(1+\mu)^{t-T}, \qquad \text{for } t=T+1,\ T+2,\ T+3,$$

Table 2-2 (continued)

Terminal inventories

$$(14.1)\quad s(T)X(T+1) = s(T)q_{\emptyset}^{-1}\,F(T)(1+\emptyset)$$

$$+\ s(T)q_{\gamma}^{-1}\,\overline{G(T)}(1+\gamma)$$

$$+\ s(T)q_{\epsilon}^{-1}\,\overline{F(T)}(1+\epsilon)$$

$$+\ s(T)q_{\delta}^{-1}\,\overline{D(T)}(1+\delta)$$

$$-\ s(T)q_{\mu}^{-1}\,M(T)(1+\mu)\,.$$

2.1.1 Objective Function

The objective function which we maximize is the present discounted value of consumption, W, over the planning period T;

$$(1) \qquad W = \sum_{t=1}^{T} \frac{C(t)}{(1+w)^{t-1}}$$

where C(t) is aggregate consumption in period t and w is the social discount rate applied to future private consumption.

The goals of economic policy are defined in a programming model not only by what is chosen to be maximized, i.e. by the content of the objective function, but also by the content of the constraints. The multiplicity of economic goals which characterizes the real world of policy making can be described by a model whose objective function embodies only one criterion with other goals entering via the model's constraints. Alternatively, it would be possible to incorporate the content of the constraints in the objective function with suitable weights. The one or other approach is, to some extent, dictated by the character of the goals. When the goals are naturally formulated as inequalities it is most convenient to have them appear as constraints. This, for example, is the case when it is desired that consumption growth be monotonic with a certain minimum rate.

Consumption Growth Constraint

Constraints are applied in most solutions which require the monotonic growth of aggregate consumption between successive periods; i.e.

$$(2) \qquad C(t+1) \geq C(t)[1+\rho(t)] \quad , \qquad \text{for } t=0, \ldots, T-1$$

where $\rho(t)$ is the prescribed minimum growth rate for aggregate private consumption in period t. This constraint permits parametric investigation of policy decisions as to the minimum intra-plan growth rates of consumption. In most cases by setting $C(\overline{0})$ to zero the constraint is made redundant in the first period in order to help insure the achievement of a solution when there are grounds for believing that otherwise no feasible solution would exist. This latter procedure permits the model to choose the level of consumption in the first period, though it remains constrained subsequently to achieving at least the minimum growth rate. There is no reason why in the absence of such constraints the model solutions would generate monotonic growth, rather finding it preferable to choose some other pattern.

In the absence of diminishing marginal utility of aggregate consumption the model would show the characteristic flip-flop tendency of the solutions of such linear models to concentrate the output of consumption goods either at the beginning or at the end of the planning period. The consumption growth constraints counter the tendency to concentrate consumption at the beginning, since increasing consumption in the early plan periods would only force still higher consumption in the later plan periods. On the other hand, if the solution tended anyway to concentrate consumption in the later plan periods, that behavior would not be restrained by the constraints on the growth of consumption. If the growth constraint is applied in the first period as compared to the pre-plan period, the level as well as the rate of growth of consumption is constrained to minimum values. Terminal conditions can be set in such a way that they may also moderate the tendency to crowd consumption into the final plan years. Therefore, although a non-linear utility function

reflecting diminishing marginal utility of aggregate consumption would be preferable on theoretical and analytical grounds to the simple objective function chosen, suitable constraints can achieve some of the same effects.[1] By linear approximations a non-linear utility function could be introduced but it would impose somewhat greater computational burdens. Even if these could be borne in a more ambitious scheme, the fundamental difficulty still would remain of making reasonable estimates of the utility function. Solutions, moreover, are likely to be sensitive to the rate at which marginal utility declines. Of course, the approach could be adapted on this issue as in other similar cases of experimenting with various utility functions and then offering the results as a menu of alternatives.

Assumption of an **arbitrary** utility function would not be any more satisfactory than the linear objective function. The coefficients of an arbitrary function most likely would be derived from an assumed desirable intertemporal distribution of consumption, in which case it is as well to use the linear objective function and to specify the distribution of consumption directly. Furthermore, such constraints may have a clearer and straightforward connotation to planners than the rate at which social marginal utility diminishes.

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1 The use of a linear objective function in place of the non-linear objective function has to be explained since optimizing a linear objective function leads to a point on the bounding feasible surface, whereas the true optimum may be an interior point in the feasible space. However the utility function of aggregate consumption over the plan period is monotonic in all dimensions. Furthermore the true maximum is outside the feasible region. These two conditions are sufficient to ensure that the true optimum is on the feasibility surface.

2.1.2 Distribution Relations

$$(3.0)\quad J(t) + H(t) + N(t) + Q(t) + F(t) + G(t) + E(t) \leq M(t) + X(t), \qquad \text{for } t=1, \ldots, T.$$

These require that the total demand for each commodity in each period not exceed the availability of that commodity in that period. Each of these terms represents a column vector. The first seven terms represent uses of the output of each sector: $J(t)$, intermediate inputs, $H(t)$, deliveries for inventory accumulation, $N(t)$, deliveries of investment goods for new fixed capital, $Q(t)$, deliveries for restoring depreciated fixed capital, $F(t)$, private consumption, $G(t)$, government consumption and $E(t)$, exports. The last two terms, $M(t)$, imports and $X(t)$, domestic production, are the sources of availability of the products.

2.1.3 Intermediate Products

The intermediate requirements for output in each period are determined, Leontief-like, by a matrix of input-output coefficients, $a(t)$;

$$(3.1)\quad J(t) = a(t)\, X(t), \qquad \text{for } t=1, \ldots, T.$$

The time subscript t of the $a(t)$ matrix indicates that intermediate requirements may change over time. This possibility is actually exploited only to a limited degree because of lack of information.

2.1.4 Inventory Accumulation

Inventory accumulation is determined in a set of accelerator-type relationships using a matrix of inventory coefficients, $s(t)$.

$$(3.20)\quad H(t) = s(t)\left\{X(t+1) - X(t)\right\}, \qquad \text{for } t=2, \ldots, T.$$

(3.21) $H(1) = s(1)\left\{X(2) - (1+\alpha_0)\,\overline{X(0)}\right\}$.

Thus, deliveries in period t for inventory are a function of the forward difference of output $\{X(t+1) - X(t)\}$. This may be slightly preferable to making current deliveries for inventory purposes depend on the backward difference in output, i.e. $\{X(t) - X(t-1)\}$ but it might be even better to have combined both formulations. Production for inventory in the first period H(1) is based on the difference between output levels in the second period and anticipated output levels in the first period. With α the vector of anticipated sectoral growth rates and $\overline{X(0)}$ the pre-plan year output levels, $s(1)(1+\alpha_0)\overline{X(0)}$ gives total stocks of inventories at the beginning of the plan.

2.1.5 Private Consumption

The vector F(t) of deliveries to private consumption is related to aggregate consumption, C(t), by a coefficient vector c(t) which define the proportions of sectoral consumption in the aggregate.

(3.3) $F(t) = c(t)C(t)$, $\qquad t=1, \ldots, T$.

$c_i(t)$ is the amount of good i in one unit of aggregate consumption C(t) and so $\sum_{i=1}^{n} c_i(t) = 1$. The specification of C(t) thus fixes the composition of aggregate consumption in period t. Since substantial variability in the composition is unlikely in the short run, in the solutions of the Target and the Transit Models c(t) is kept constant for all the periods of the plan. At low levels of income and under the still powerful influence of tradition there is relatively little substitution, particularly among

such grossly defined sectors as those used here. The Indian market basket of consumption goods, like that of other countries at such low income levels, is relatively simple and dominated by staples. While the income and expenditure elasticities of consumption for metal or plastic items may be quite high, they are consumed in such small quantities that their fraction of total consumption is not likely to change substantially within five years. It would be particularly mistaken to believe that such products would be substituted for staples if the latter goods should become relatively scarce. In any case, the formulation of the problem with fixed consumption proportions is not meant to be a permanent commitment. The proportions can be changed exogenously from solution to solution to study the effects of alternative compositions.

The sectoral proportions of consumption are determined by consumption-expenditure elasticities in the Guidepath and Guidepost Models. The latter modification could easily be introduced in the Target and Transit Models as well and was not mainly because it would have little effect on the general character of the solutions. Neither formulation really satisfies the goal of making the consumption composition responsive to relative prices and, thus, to relative scarcities. With additional computational requirements the consumption proportions could themselves be allowed to vary within specified limits and the optimizing mechanism would then choose the set of limits which permitted the greatest total of consumption goods to be produced. Or only the minimum amounts of each type of consumption could be specified and the solution would decide in which types of consumption goods production the limits would be exceeded and relative specialization would occur. The latter procedure is likely to lead to

concentration on Services beyond the minimums since this sector is by far and away the easiest to expand. So a combination of these latter two approaches might be more desirable than either separately. Still none of these methods makes the sectoral consumption levels fully responsive to relative prices. A utility function which includes the possibility of substitution among sectors would do so but empirical information on cross elasticities is lacking. While not a major problem as long as the sectors are highly aggregated as in the computations to follow, it would become more important to simulate price-substitution processes perhaps by the devices described when the sectors are sufficiently disaggregated to make such substitution meaningful.

2.1.6 Government Consumption

The requirements for government's consumption from each sector in each period are specified exogenously. If $G(t)$ is the vector of government consumption in period t, then

$$(3.4) \qquad G(t) = \overline{G(t)}, \qquad \text{for } t=1, \ldots, T.$$

This exogenous specification is not completely justified. Government consumption is not independent of the level and growth rate of output, either on the demand side or supply side. Education provides a good example of this interdependence. Private demands certainly rise with income and the government responds by trying to meet the demand even though much of the demand can hardly be considered an increment to productive capacity. On the other hand, government engineering colleges provide additional scarce inputs without which the system would not run nearly so well. Similar observations can be made about government health

services. We do not attempt to introduce these considerations into the model by relating government consumption to other variables.

2.1.7 Exports

E(t), the vector of exports in period t, is specified exogenously

(3.5) $E(t) = \overline{E(t)}$, for t=1, ..., T.

However, exports are not truly exogenous, since except in extreme cases they depend on domestic prices which in turn depend on the level and composition of output. This sophistication is beyond linear models.

2.1.8 Capacity Restraints

These ensure by means of the diagonal matrix b of aggregate capital output ratios that output in each sector in each period does not exceed that producible with the fixed capital in that sector available at the beginning of that period.

(4.0) $b(t)X(t) \leq K(t)$, for t=1, ..., T.

K(t) is the vector of fixed capital available at the beginning of period t.

A different b matrix might be associated with each specific vintage of capital but that is not done here.

2.1.9 Investment Requirements

The total capital in each sector, represented by an element of the vector K(t), is a composite commodity with a fixed composition. This composition is defined by a proportion matrix p, in which element p_{ij} represents the good i held as fixed capital by sector j per unit of composite fixed capital K_j.

Sectoral capacities may be increased in any period t by the delivery of additions to capacity, Z(t). These increments of capacity, in turn, are formed by deliveries of output from the sectors which produce investment goods. The deliveries are in fixed proportions and with fixed time leads of one, two and three periods prior to the completion of the addition to capacity. The amount of Z(t) which must be furnished by each sector in each period is determined by the three investment lag proportion matrices p', p'', p'''. The coefficients, p'_{ij}, p''_{ij}, p'''_{ij}, in these matrices indicate the proportion of the total increment to capacity in sector j in period t which must be supplied by sector i in periods t-1, t-2, and t-3.[1] Thus, the total amount of deliveries of investment goods in each period is

$$(5.0) \qquad N(t) = p'Z(t+1) + p''Z(t+2) + p'''Z(t+3) , \qquad \text{for } t=1, \ldots, T.$$

The assumptions of fixed proportions and time sequences which we have made in the relations which describe investment formation are not completely accurate descriptions of reality. In particular, since the output of each sector is homogeneous it would be possible as an alternative procedure to make capital-in-process non-specific and to indicate only the total contribution of each capital goods sector to output. This would allow investment goods to be produced in advance of the actual increment in capacity whenever the model decided it was most convenient. The latter formulation would provide for flexibility in the sequence of capital

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1 The matrices p', p'' and p''' have a simple relationship to p p_{ij} being $= p'_{ij} + p''_{ij} + p'''_{ij}$.

formation making it possible for the model to stretch out the lags beyond the specified minimum lags if it is preferable to do so. This, in turn, would undoubtedly improve somewhat the overall performance of the model solutions. It would require, however, a more careful accounting of the production of capital goods by each sector, its movement into use or into an inventory of "unfinished capacity" and its withdrawal from that inventory. That would, in turn, increase the number of restraints. Since the model is likely to use the additional freedom only in the initial periods, the additional computational burden was not considered worthwhile. Moreover, if the model were given this additional freedom in scheduling investment, it would use it, if at all, by totally interrupting investment in some year. Since there are costs to such a complete interruption which are not easily accounted for in a linear framework we chose not to permit this freedom.

2.1.10 Depreciated Capital

Real depreciation depends on the passage of time in this model rather than the rate of use. The depreciation pattern chosen is the "one hoss shay" type, again because of the desire for simplicity and the limitations of ignorance. Since lifetimes of plant and equipment are chosen to be, respectively, thirty-three and twenty years, the disappearance of productive capacity through depreciation is exogenously determined in full for twenty years and in part for thirteen more years.

The capital originating in sector i which wears out in sector j is $D_{ij}(t)$. The total depreciated capital in each sector in each period is then $D_j = \sum_i D_{ij}(t)$ and for all sectors

(5.1) $\quad D(t) = \overline{D(t)}, \qquad$ for $t=1, \ldots, T+3$.

2.1.11 Depreciated Capacity

The different lifetimes imply that plant and equipment depreciate in an "unbalanced" manner. This, in turn, provides the opportunity for restoring capacity by an unbalanced production of capital of the plant or equipment type. Since the components of the capital stock in each sector wear out at different rates the capacity which is immobilized by the depreciation of the components must be computed. The depreciation composition matrix r is defined with element $r_{ij} = D_{ij}/D_j$. Then multiplying $D_j(t)$ by r_{ij}/p_{ij} the amount of capacity which would be lost due to depreciation of each component $D_{ij}(t)$ in sector j is computed. The actual amount of capacity lost through depreciation in sector j is the largest loss due to the wearing out of any component and is determined by the maximum of $D_j(r_{1j}/p_{1j}, r_{2j}/p_{2j}, \ldots, r_{nj}/p_{nj})$. Therefore, the diagonal matrix d can be formed whose element $d_{jj} = \text{Maximum}\ (r_{1j}/p_{1j}, r_{2j}/p_{2j}, \ldots, r_{nj}/p_{nj})$. The capacity lost through depreciation in each sector is, therefore,

$$(5.2) \quad V(t) = [d]D(t) , \qquad \text{for } t=1, \ldots, T+3.$$

2.1.12 Restoration Requirements

It is up to the optimizing mechanism to decide on R(t) the amount of the capacity lost through depreciation which will be restored. The model may, in fact, decide to restore only part of that capacity. This is likely to happen only when the patterns of depreciating capacity are substantially different from the proportions in which capacity is desired in the future.

The deliveries Q(t) from each sector for capacity restoration, R(t), are assumed, like new capital formation, to require up to three periods.

So the deliveries for this purpose in any one period look three periods ahead

$$(5.3)\quad Q(t) = r'[d]^{-1}R(t+1) + r''[d]^{-1}R(t+2) + r'''[d]^{-1}R(t+3), \qquad \text{for } t=1, \ldots, T.$$

where r', r'' and r''' are restoration lag proportion matrices similar to p', p'' and p'''. The coefficients r'_{ij}, r''_{ij} and r'''_{ij} indicate the proportions of the total capital replacement due in period t in sector j, $\frac{R_j(t)}{d_{jj}}$, to restore capacity $R_j(t)$ which must be supplied by sector i in periods t+1, t+2 and t+3.

2.1.13 Capital Accounting Relationships

Having described the manner in which capital is created, depreciates and is replaced, the accounting relationships for capacity in each sector can now be written as

$$(5.4)\quad K(t+1) \leq K(t) + Z(t+1) + R(t+1) - V(t+1), \qquad \text{for } t=1, \ldots, T+2.$$

This merely states that capital available at the beginning of period t+1, K(T+1), cannot be greater than the capital available in the preceding period less the capacity depreciating in period t plus the new, completed additions to capacity plus that part of depreciated capacity that is restored. Since both the restored capacity R(t+1) and new capacity Z(t+1) can be zero, this permits decumulation of capital to the extent of V(t+1).

We have assumed in this formulation that if capacity is to be restored when any component of capital depreciates the restoration must take place in the same period in which the depreciation occurs. This means that even

undepreciated components of capital are lost if restoration is not carried out in that period.[1]

2.1.14 Restoration Ceilings

Since a unit of capacity can be created more cheaply by restoring a worn out component than by supplying the entire set of components of the composite capital, the model has to be restrained from restoring in any period more capacity than that which is depreciated.

$$(6.0) \qquad R(t) \leq V(t), \qquad \text{for } t=1, \ldots, T+3.$$

2.1.15 The Balance of Payments Constraints

The total amount of imports, $\sum_{i=1}^{n} M_i(t)$, in each period is limited by the availability of foreign exchange. This in turn depends on the total amount of exports, $\sum_{i=1}^{n} E_i(t)$, foreign aid from government sources, private foreign investment and whatever changes in reserves will be tolerated. The latter three components, lumped together, are specified exogenously as $\overline{A(t)}$. The balance of payments constraint becomes

$$(7.0) \qquad \mathcal{U}M(t) \leq \overline{A(t)} + \mathcal{U}E(t), \qquad \text{for } t=1, \ldots, T.$$

where $\mathcal{U}$ is a unit row vector [1, 1, 1, ..., 1].

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1 It would be possible to avoid this limiting assumption by changing the constraints (6.0) on restoration ceilings, described next, to

$$\sum_{t=1}^{t} R(t) < \sum_{t=1}^{t} V(t), \qquad t=1, \ldots, T+3.$$

This would provide the freedom to restore depreciated capital in any period subsequent to its depreciation.

2.1.16 Composition of Imports

The next step is to provide for the allocation of the total import potential among the various sectors. First of all, some sectors such as construction and electric power generation are not allowed to import at all so the import terms in those sectors are set at zero. Secondly, in each period some imports are non-competitive in the sense that these are goods for intermediate as well as final use for which no domestic capacity exists. Non-competitive imports in this way complement domestic production. Strictly speaking, accounting for these imports requires creating a separate sector for each type. Rather than do that, the vector of non-competitive imports, $M'(t)$, is defined here as import requirements which are related to output levels by fixed coefficients and which must be satisfied before other imports are allowed. $M''(t)$ can be classified without recourse to special devices in their corresponding domestic sectors. Total imports in each sector are the sum of the two types.

$$(8.0) \quad M(t) = M'(t) + M''(t), \qquad \text{for } t=1, \ldots, T.$$

Non-competitive imports are related to domestic outputs by the diagonal matrix $m'(t)$ of fixed import coefficients so that

$$(8.1) \quad M'(t) = m'(t)X(t), \qquad \text{for } t=1, \ldots, T.$$

This simple treatment of non-competitive imports does not permit planning of import substitution programs. However, we believe that for planning import substitution program a much more disaggregated sectoral classification is required than the one we have used. It would be desirable to make the import coefficients functions of the existence of domestic

capacity but this would introduce non-linearity into the system. However, non-competitive import coefficients can be changed period by period to take into account the planned programs of import substitution.

2.1.17 Competitive Import Ceilings

Equation (8.1) has the effect of determining the minimum amount of imports necessary for producing the domestic output X(t). Once the minimums are satisfied, the remaining foreign exchange should be used where it is most valuable, and the creation of domestic capacity depends on this use. Competitive imports make use of whatever foreign exchange is left after non-competitive imports are satisfied.

While non-competitive imports are complements to domestic production, competitive imports, M"(t), are substitutes. Their amounts are determined by the model solution subject to the availability of foreign exchange. In the absence of diminishing returns the model solution would specialize competitive imports in only a few sectors. This would unduly restrict domestic capacity formation in these sectors. To avoid this possibility the maximum usage of foreign exchange for competitive imports is stipulated for each sector in

$$(8.2) \quad M''(t) \leq m''(t)\ [A(t) + \mathcal{U}E(t) - \mathcal{U}M'(t)], \qquad \text{for } t=1, \ldots, T.$$

where the vector of coefficients m"(t) is exogenously prescribed so that $\sum_i m''_i(t) > 1$. This gives the model some leeway in allocating foreign exchange to competitive imports. The formulation also has the advantage of recognizing the political and administrative obstacles to drastic reallocations of foreign exchange resources from period to period. The

inequality in (8.2) may be interpreted as reflecting this realistic limitation. In some of the solutions, however, the constraint in (8.2) will be nullified by setting all the m''_i equal to unity so that the model has complete freedom to allocate foreign exchange for competitive imports.

2.1.18 Initial Capital Stock and Capital in Process

Events within the plan period are related to what has gone before and what comes after as can be seen in a number of the relationships. In the capacity restraints in (4.0), for example, the capital stocks available at the outset of the plan period must be known. Equation (5.4) also indicates the need for somehow determining the levels of capital in process at the beginning and end of the plan. In the Basic Model core we need only add the description of how the model is started.

The capital stock available at the beginning of the first year of the plan is greater than that which produced the output of the pre-plan period since additional investment will mature and become available by the end of the pre-plan period or beginning of the first plan period. It is this latter capital capacity which is the initial capacity for the plan. In addition, the investment undertaken in the pre-plan period to mature in periods two and three must also be specified. Alternatively, the maximum gross increments in capacity which can be delivered in periods 2 and 3 can be stipulated since it is rigidly linked to pre-plan investment. This does not commit the solution to the completion of the projects started before the plan period; that is a matter to be decided by the optimization procedure.

These initial conditions should be based on empirical information available before the plan begins. Practically, however, no information

has been available to us as to the amounts of uncompleted capital in process at the beginning of each plan period. Even though the Third Five Year Plan refers to projects started during the Second Plan to be completed during the Third Plan, the information in the plan is not sufficient to estimate either the sectoral composition or the degree of completion of such projects at the beginning of the Third Plan. Similarly adequate information is not publicly available for the Fourth Plan period.

It would have been possible to estimate the capital stocks available during the first three periods of the Third Plan from the output levels achieved in these three years. Yet our objective is to simulate the planning process as it is confronted before the beginning of the plan. Consequently the initial conditions are estimated by assuming that in the pre-plan period for each sector a growth rate, α_{bi}, has been projected for the creation of capital. The initial conditions thus become:

$$K(1) = b(1)(I + \alpha_0)\overline{X(0)} \tag{9.0}$$

$$Z(2) + R(2) \leq b(2)(I + \alpha_0)\alpha_0\overline{X(0)} + V(2) \tag{9.10}$$

$$Z(3) + R(3) \leq b(3)(I + \alpha_0)^2\alpha_0\overline{X(0)} + V(3) \tag{9.11}$$

where α_0 is a diagonal matrix of sectoral growth rates α_{0i}.

2.1.19 Terminal Requirements

The optimum short run plan would be a detailed working out of a longer plan which embodied the distant as well as current goals of society. Making longer plans, however, requires information which the future hides. Analytical and computational problems force the truncation of the planning period. The choice of the plan period, however, depends, among other

factors, on the uncertainties associated with the future. In Chapter 5 techniques will be presented of making and coordinating long and short plans. In this chapter we consider only the conventional five year plan period.

Since our objective function is a weighted sum of aggregate consumption within the plan years, terminal requirements have to be set up as constraints in order to reflect the goals of the post-plan future. Alternatively terminal conditions could have been embodied in the objective function. Current economic policy decisions should reflect the reality of an unbroken chain of economic relationships leading from the past into the future. The stocks of fixed capital, of inventories and of capital in process are the only links in that chain in our models. Specification of these stocks at the end of the plan period determines the future alternatives which are available to the economy.

In general then the terminal requirements have to state the desired minimum levels of these stocks:

(10.01) $K(T+1) \geq \overline{K(T+1)}$,

(10.02) $K(T+2) \geq \overline{K(T+2)}$,

(10.03) $K(T+3) \geq \overline{K(T+3)}$,

and

(10.1) $s(T)X(T+1) \geq \overline{X_s(T+1)}$.

where $\overline{X_s(T+1)}$ is the vector of stocks of inventories at the beginning of the first post-plan period, T+1, i.e. at the end of the plan.

$\overline{K(T+1)}$, $\overline{K(T+2)}$, $\overline{K(T+3)}$ and $\overline{X_s(T+1)}$ are prescribed in two alternative ways in the Target Model and the Transit Model.

2.2 The Target Model

In this model the levels of the terminal stocks are specified exogenously. Neither the methods of determining those particular levels nor the reasons for desiring them is the concern of the Target Model. It merely investigates the allocational implications of the targets for the plan period. In general $\overline{K(T+1)}$, $\overline{K(T+2)}$, $\overline{K(T+3)}$ and $\overline{X_s(T+1)}$ will have to be specified. The required minimum capital in process at the end of period T is determined by K(T+2) and K(T+3) because of the assumed lag of up to three periods between investment and maturity of capital. Alternatively the levels of terminal stocks may be defined in terms of $\overline{X(T)}$, the levels of output for the terminal year which are set as targets as, for example, in Indian planning.

Since there are no post-terminal conditions explicit in the specifications of $\overline{X(T)}$ it is necessary to project some in order to operate the model. The assumption adopted is simply that each sector grows post terminally at the annual sectoral growth rate, α_{Ti}, which is implied between $\overline{X(T)}$ and $\overline{X(0)}$. We obtain K(T+1), K(T+2) and K(T+3) from X(T+1), X(T+2) and X(T+3) using the diagonal matrix, b, of capital output ratios. That is:

(11.01) $K(T+1) \geq b(T)[I + \alpha_T]\overline{X(T)}$,

(11.02) $K(T+2) \geq b(T)[I + \alpha_T]^2\overline{X(T)}$,

(11.03) $K(T+3) \geq b(T)[I + \alpha_T]^3\overline{X(T)}$.

and

(11.1) $s(T)X(T+1) \geq s(T)(I + \alpha_T)\overline{X(T)}$.

With these terminal conditions added to the Basic Model core, we have a model which can be used to investigate the implication of a set of Plan targets. The solution calculates all the direct and indirect requirements implied by the targets, if at all feasible, allocates resources to their production, and simultaneously distributes the use of resources over time in such a way as to maximize the discounted consumption in the objective function. If the solution indicates the targets are not feasible, no allocation of resources can be found to meet them. If the targets are feasible, no other allocation of resources will reach the targets and produce a larger value of discounted consumption.

To reduce the number of restraints for computation purposes all the equalities are substituted into various inequalities. Table 2-3 shows the final form of the restraints as they were programmed for the computer as the Target Model. Table 2-4 shows the Tableau of the Target Model. In the tableau the dual relations are clearly seen and provide a useful reference in interpreting the shadow prices.

2.3 The Transit Model

This is a short-term model covering the conventional planning period of five years like the Target Model. In this case, however, the model has more freedom in that it determines its own targets from the specifications on the exogenous uses of output and growth rates. The technique used for this purpose is a variation of that presented by

Table 2-3

The Target Model Constraints After Substitutions

(1) Objective function

(1.0) Maximize: $W = \sum_{t=1}^{T} \frac{C(t)}{(1+w)^{t-1}}$.

Subject to:

(2) Consumption growth constraints

(2.01) $-C(1) \leq -(1+\rho(0))\overline{C(0)}$,

(2.02) $-C(t+1) + (1+\rho(t))C(t) \leq 0$, $t=1, \ldots, T-1$,

(3) Distribution relations

(3.01) $[a(1)-I-m'(1)]X(1) + s(1)X(2) + p'Z(2) + p''Z(3) + p'''Z(4)$
$+ r'd^{-1}R(2) + r''d^{-1}R(3) + r'''d^{-1}R(4) + c(1)C(1) - M''(1)$
$\leq s(1)[I+\alpha_0]\overline{X(0)} - \overline{E(1)} - \overline{G(1)}$,

(3.02) $[a(t)-I-m'(t)-s(t)]X(t) + s(t)X(t+1) + p'Z(t+1) + p''Z(t+2) + p'''Z(t+3)$
$+ r'd^{-1}R(t+1) + r''d^{-1}R(t+2) + r'''d^{-1}R(t+3) + c(t)C(t) - M''(t)$
$\leq -\overline{E(t)} - \overline{G(t)}$, for $t=2, \ldots, T-1$,

(3.03) $[a(T)-I-m'(T)-s(T)]X(T) + p'Z(T+1) + p''Z(T+2) + p'''Z(T+3)$
$+ r'd^{-1}R(T+1) + r''d^{-1}R(T+2) + r'''d^{-1}R(T+3) + c(T)C(T) - M''(T)$
$\leq -\overline{E(T)} - \overline{G(T)} - s(T)(I+\alpha_T)\overline{X(T)}$,

(4) Capacity restraints

(4.01) $b(1)X(1) \leq b(1)(I+\alpha_0)\overline{X(0)}$,

(4.02) $b(t)X(t) - K(t) \leq 0$,

(5) Capital accounting relations

(5.01) $K(2) - Z(2) - R(2) \leq b(1)(I+\alpha_0)\overline{X(0)} - d\overline{D(2)}$,

(5.02) $K(t+1) - Z(t+1) - R(t+1) - K(t) \leq -d\overline{D(t+1)}$, for $t=2, \ldots, T-1$,

Table 2-3 (continued)

(5.03) $-Z(T+1) - R(T+1) - K(T) \leq -d\overline{D(T+1)} - b(T)(I + \alpha_T)\overline{X(T)}$,

(5.04) $-Z(T+2) - R(T+2) - Z(T+1) - R(T+1) - K(T) \leq -d\overline{D(T+1)} - d\overline{D(T+2)}$
$- b(T)(I + \alpha_T)^2\overline{X(T)}$,

(5.05) $-Z(T+3) - R(T+3) - Z(T+2) - R(T+2) - Z(T+1) - R(T+1) - K(T)$
$\leq -d\overline{D(T+1)} - d\overline{D(T+2)} - d\overline{D(T+3)} - b(T)(I + \alpha_T)\overline{X(T)}$,

(6) Restoration ceilings

(6.0) $R(t) \leq d\overline{D(t)}$, for $t=2, \ldots, T+3$,

(7) Balance of payments constraints

(7.0) $\mu m'(t)X(t) + \mu M''(t) \leq \overline{A(t)} + \mu\overline{E(t)}$, for $t=1, \ldots, T$,

(8) Competitive import ceilings

(8.0) $[m''(t)]^{-1}M''(t) + \mu m'(t)X(t) \leq \overline{A(t)} + \mu\overline{E(t)}$, for $t=1, \ldots, T$,

(9) Initial capital in process restraints

(9.01) $Z(2) + R(2) \leq b(2)\alpha_0(I + \alpha_0)\overline{X(0)} + d\overline{D(2)}$,

(9.02) $Z(3) + R(3) \leq b(3)\alpha_0(I + \alpha_0)^2\overline{X(0)} + d\overline{D(3)}$.

TABLE 2—4

TABLEAU FOR THE TARGET MODEL

Constraints \ Variables		X(1)	C(1)	M"(1)	X(2)	C(2)	M"(2)	K(2)	Z(2)	R(2)	X(3)	C(3)	M"(3)	K(3)	Z(3)	R(3)	X(4)	C(4)
(1) Objective			1.0			$(1+w)^{-1}$						$(1+w)^{-2}$						$(1+w)^{-3}$
(2) Consumption Growth Constraints	1		-1															
	2		$(1+\rho)$			-1												
	3					$(1+\rho)$						-1						
	4											$(1+\rho)$						-1
	5																	$(1+\rho)$
(3) Distribution Relations	1	[a-l-m']	[c]	-[l]	[s]				[p']	[r'][d]$^{-1}$					[p"]	[r"][d]$^{-1}$		
	2				[a-l-m'-s]	[c]	-[l]				[s]				[p']	[r'][d]$^{-1}$		
	3										[a-l-m'-s]	[c]	-[l]				[s]	
	4																[a-l-m'-s]	[c]
	5																	
(4) Capacity Restraints	1	[b]																
	2				[b]			-[l]										
	3										[b]			-[l]				
	4																[b]	
	5																	
(5 Capital Accounting Relations	1							[l]	-[l]	-[l]								
	2							-[l]						[l]	-[l]	-[l]		
	3													-[l]				
	4																	
	5																	
	6																	
	7																	
(6) Restoration Ceilings	2									[l]								
	3															[l]		
	4																	
	5																	
	6																	
	7																	
	8																	
(7) Foreign Trade Balance	1	um'		u														
	2				um'		u											
	3										um'		u					
	4																um'	
	5																	
(8) Competitive Import Ceilings	1	um'		[m"]$^{-1}$														
	2				um'		[m"]$^{-1}$											
	3										um'		[m"]$^{-1}$					
	4																um'	
	5																	
(9) Initial Capital in Process	2								[l]	[l]								
	3														[l]	[l]		

M''(4)	K(4)	Z(4)	R(4)	X(5)	C(5)	M''(5)	K(5)	Z(5)	R(5)	Z(6)	R(6)	Z(7)	R(7)	Z(8)	R(8)	≷	R.H.S.
					$(1+w)^{-4}$												
																≤	$-(1+\rho(0))\overline{C(0)}$
																≤	0
																≤	0
																≤	0
					-1											≤	0
		[p''']	[r'''][d]$^{-1}$					[p''']	[r'''][d]$^{-1}$							≤	$-\overline{E(1)}-\overline{G(1)}+s(1)[1+\varpi_0]\overline{X(0)}$
		[p'']	[r''][d]$^{-1}$					[p'']	[r''][d]$^{-1}$	[p''']	[r'''][d]$^{-1}$					≤	$-\overline{E(2)}-\overline{G(2)}$
		[p']	[r'][d]$^{-1}$					[p']	[r'][d]$^{-1}$	[p'']	[r''][d]$^{-1}$	[p''']	[r'''][d]$^{-1}$			≤	$-\overline{E(3)}-\overline{G(3)}$
				[s]						[p']	[r'][d]$^{-1}$	[p'']	[r''][d]$^{-1}$			≤	$-\overline{E(4)}-\overline{G(4)}$
-[1]				[a-l-m'-s]	|c|	-[1]								[p''']	[r'''][d]$^{-1}$	≤	$-\overline{E(5)}-\overline{G(5)}-s(6)[1+\varpi_T]\overline{X(5)}$
																≤	$[b][1+\varpi_0]\overline{X(0)}$
																≤	0
																≤	0
	-[1]															≤	0
				[b]			-[1]									≤	0
																≤	$-[d]\overline{D(2)}+[b][1+\varpi_0]\overline{X(0)}$
																≤	$-[d]\overline{D(3)}$
																≤	$-[d]\overline{D(4)}$
	[1]	-[1]	-[1]													≤	$-[d]\overline{D(5)}$
	-[1]						[1]	-[1]	-[1]							≤	$-[d]\overline{D(6)}-[b][1+\varpi_T]\overline{X(5)}$
							-[1]			-[1]	-[1]					≤	$-[d]\overline{D(6)}-[d]\overline{D(7)}-[b][1+\varpi_T]^2\overline{X(5)}$
							-[1]			-[1]	-[1]	-[1]	-[1]			≤	$-[d]\overline{D(6)}-[d]\overline{D(7)}-[d]\overline{D(8)}-[b][1+\varpi_T]^3\overline{X(5)}$
							-[1]			-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	≤	
																≤	$[d]\overline{D(2)}$
																≤	$[d]\overline{D(3)}$
																≤	$[d]\overline{D(4)}$
			[1]													≤	$[d]\overline{D(5)}$
									[1]							≤	$[d]\overline{D(6)}$
											[1]					≤	$[d]\overline{D(7)}$
													[1]			≤	$[d]\overline{D(8)}$
															[1]	≤	
																≤	$\overline{A(1)}+u\,\overline{E(1)}$
																≤	$\overline{A(2)}+u\,\overline{E(2)}$
																≤	$\overline{A(3)}+u\,\overline{E(3)}$
																≤	$\overline{A(4)}+u\,\overline{E(4)}$
u																≤	$\overline{A(5)}+u\,\overline{E(5)}$
				um'		u											
																≤	$\overline{A(1)}+u\,\overline{E(1)}$
																≤	$\overline{A(2)}+u\,\overline{E(2)}$
																≤	$\overline{A(3)}+u\,\overline{E(3)}$
																≤	$\overline{A(4)}+u\,\overline{E(4)}$
[m'']$^{-1}$																≤	$\overline{A(5)}+u\,\overline{E(5)}$
				um'		[m'']$^{-1}$											
																≤	$[d]\overline{D(2)}+[b][\varpi_0][1+\varpi_0]\overline{X(0)}$
																≤	$[d]\overline{D(3)}+[b][\varpi_0][1+\varpi_0]^2\overline{X(0)}$

Chakravarty and Eckaus and by Stone and Brown.[1]

In this model terminal conditions are provided which guarantee the achievement in the post-terminal period of exogenously specified growth rates of deliveries for private consumption, replacement, government consumption, exports and imports from the levels and composition of these deliveries in the last year of the plan. The fixed capital capacities and inventory investment consistent with these stipulations are deduced. The level of aggregate consumption C(T) and the composition of imports M(T) in the last period are endogenously determined by the model. Consequently the levels of terminal stocks are themselves determined as part of the solution of the model. If the minimum level of consumption is also specified by means of the consumption growth constraint and a prescribed $\overline{C(0)}$, then a minimum post-terminal consumption level and growth rate is stipulated for the post-terminal period as well. While it is desirable to allow the composition of imports to be determined by the optimizing mechanism during the plan period, this mechanism does not work in the post-plan period. Thus, it becomes necessary to provide some basis for extrapolating the composition of imports and in this case it is taken to be the import levels of the final plan period.

Again three post-terminal periods must be accounted for because of the three period gestation lag in investment. The presentation will initially assume a constant post-terminal composition of consumption by adopting the same growth rate for use in each sector. Thus with post-terminal growth rates, ϕ, δ, γ, ϵ, μ, for consumption, replacement,

1 S. Chakravarty and R. S. Eckaus, "An Approach to a Multisectoral Planning Model," in Capital Formation and Economic Development, P. N. Rosenstein-Rodan, ed., Cambridge, 1964 and R. Stone and A. Brown, A Computable Model of Economic Growth.

government, exports and imports respectively from their levels in the terminal periods, we have

$$\left.\begin{aligned}
&(12.01)\quad F(t) = F(T)(1+\phi)^{t-T},\\
&(12.02)\quad G(t) = \overline{G(T)}(1+\gamma)^{t-T},\\
&(12.03)\quad E(t) = \overline{E(T)}(1+\epsilon)^{t-T},\\
&(12.04)\quad D(t) = \overline{D(T)}(1+\delta)^{t-T},\\
&(12.05)\quad M(t) = M(T)(1+\mu)^{t-T},
\end{aligned}\right\}\qquad \text{for } t \geq T.$$

With these assumptions the distribution equation in the post-terminal periods become

$$\begin{aligned}
(12.1)\quad X(t) = a(T)X(t) &+ (s(T) + b(T)p')[X(t+1) - X(t)]\\
&+ b(T)p''\,[X(t+2) - X(t+1)]\\
&+ b(T)p'''\,[X(t+3) - X(t+2)]\\
+ F(T)(1+\phi)^{t-T} &+ \overline{G(T)}(1+\gamma)^{t-T} + \overline{E(T)}(1+\epsilon)^{t-T} + \overline{D(T)}(1+\delta)^{t-T}\\
&- M(T)(1+\mu)^{t-T}, \qquad \text{for } t > T.
\end{aligned}$$

The post-terminal output levels can then be found as a particular solution of the distribution equations (12.1).

$$\begin{aligned}
(13.0)\quad X(t) = {} & [I-a(T)-(b(T)p'(T)+s(T))\phi-b(T)p''(T)(1+\phi)\phi-b(T)p'''(T)(1+\phi)^2\phi]^{-1}F(T)(1+\phi)^{t-T}\\
&+ [I-a(T)-(b(T)p'(T)+s(T))\gamma-b(T)p''(T)(1+\gamma)\gamma-b(T)p'''(T)(1+\gamma)^2\gamma]^{-1}\overline{G(T)}(1+\gamma)^{t-T}\\
&+ [I-a(T)-(b(T)p'(T)+s(T))\epsilon-b(T)p''(T)(1+\epsilon)\epsilon-b(T)p'''(T)(1+\epsilon)^2\epsilon]^{-1}\overline{E(T)}(1+\epsilon)^{t-T}\\
&+ [I-a(T)-(b(T)p'(T)+s(T))\delta-b(T)p''(T)(1+\delta)\delta-b(T)p'''(T)(1+\delta)^2\delta]^{-1}\overline{D(T)}(1+\delta)^{t-T}\\
&- [I-a(T)-(b(T)p'(T)+s(T))\mu-b(T)p''(T)(1+\mu)\mu-b(T)p'''(T)(1+\mu)^2\mu]^{-1}M(T)(1+\mu)^{t-T},\\
&\qquad\qquad \text{for } t=T+1,\ T+2,\ T+3.
\end{aligned}$$

From which using b(T) and s(T) and defining

$$q_\eta = [I-a(T)-(b(T)p'(T)+s(T))\eta-b(T)p''(T)(1+\eta)\eta-b(T)p'''(T)(1+\eta)^2\eta],$$

$$\text{for } \eta = \emptyset, \gamma, \epsilon, \delta, \mu,$$

the terminal requirements for the Transit Model are obtained.

Terminal capital stocks:

$$\begin{aligned}(14.0)\quad K(t) \geq\ & b(T)q_\emptyset^{-1}\ F(T)(1+\emptyset)^{t-T} \\ & + b(T)q_\gamma^{-1}\ \overline{G(T)}(1+\gamma)^{t-T} \\ & + b(T)q_\epsilon^{-1}\ \overline{E(T)}(1+\epsilon)^{t-T} \\ & + b(T)q_\delta^{-1}\ \overline{D(T)}(1+\delta)^{t-T} \\ & - b(T)q_\mu^{-1}\ M(T)(1+\mu)^{t-T}, \qquad \text{for } t=T+1,\ T+2,\ T+3,\end{aligned}$$

and

Terminal inventories

$$\begin{aligned}(14.1)\quad s(T)X(T+1) =\ & s(T)q_\emptyset^{-1}\ F(T)(1+\emptyset) \\ & + s(T)q_\gamma^{-1}\ \overline{G(T)}(1+\gamma) \\ & + s(T)q_\epsilon^{-1}\ \overline{E(T)}(1+\epsilon) \\ & + s(T)q_\delta^{-1}\ \overline{D(T)}(1+\delta) \\ & - s(T)q_\mu^{-1}\ M(T)(1+\mu).\end{aligned}$$

Again, the equalities are substituted into the inequalities and the final form of restraints programmed as Transit Model is shown in Table 2-5. The corresponding tableau is given in Table 2-6.

The assumption that in any one use all sectors grow at the same rate can be easily dropped. In the general case the growth rates $\emptyset$, δ, γ, ϵ, and μ may each be vectors of growth rates. The solution as a result only becomes somewhat more tedious than before and in fact, (12.0) could be reinterpreted for this case. Each of vectors F(t), D(t), G(t), E(t) and M(t) can be represented as a sum of n vectors each with its own scalar growth rate, e.g.

$$F(t) = \begin{Bmatrix} F_1(T) \\ 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{Bmatrix} (1+\emptyset_1)^{t-T} + \begin{Bmatrix} 0 \\ F_2(T) \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{Bmatrix} (1+\emptyset_2)^{t-T} + \ldots +$$

$$\begin{Bmatrix} 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \\ F_i(T) \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{Bmatrix} (1+\emptyset_i)^{t-T} + \ldots + \begin{Bmatrix} 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \\ F_n(T) \end{Bmatrix} (1+\emptyset_n)^{t-T} .$$

Then one would just evaluate equation (13.0) n times taking each of the n terms of the above representation in turn. Dropping the equiproportional growth rate assumption permits the exercise of discretion as to possible variation in the post-terminal growth rates for the various sectors' outputs in their different uses.

Table 2-5

The Transit Model Constraints After Substitutions

(1) Objective function

(1.0) Maximize: $W = \sum_{t=1}^{T} \frac{C(t)}{(1+w)^{t-1}}$

Subject to:

(2) Consumption growth constraints

(2.01) $-C(1) \leq -(1+\rho(0))\overline{C(0)}$,

(2.02) $-C(t+1) + (1+\rho(t))C(t) \leq 0$, $\quad t=1, \ldots, T-1$.

(3) Distribution relations

(3.01) $[a(1)-I-m'(1)]X(1) + s(1)X(2) + p'Z(2) + p''Z(3) + p'''Z(4)$
$+ r'd^{-1}R(2) + r''d^{-1}R(3) + r'''d^{-1}R(4) + c(1)C(1) - M''(1)$
$\leq s(1)[I+\alpha_0]\overline{X(0)} - \overline{E(1)} - \overline{G(1)}$,

(3.02) $[a(t)-I-m'(t)-s(t)]X(t) + s(t)X(t+1) + p'Z(t+1) + p''Z(t+2) + p'''Z(t+3)$
$+ r'd^{-1}R(t+1) + r''d^{-1}R(t+2) + r'''d^{-1}R(t+3) + c(t)C(t) - M''(t)$
$\leq -\overline{E(t)} - \overline{G(t)}$, $\quad$ for $t=2, \ldots, T-1$,

(3.03) $[a(T)-I-m'(T)-s(T)]X(T) + p'Z(T+1) + p''Z(T+2) + p''Z(T+3) + r'd^{-1}R(T+1)$
$+ r''d^{-1}R(T+2) + r'''d^{-1}R(T+3) + [c(T)+s(T)q_{\phi}^{-1}(1+\phi)c(T)]C(T)$
$- [I+s(T)q_{\mu}^{-1}(1+\mu)]M''(T) - s(T)q_{\mu}^{-1}(1+\mu)m'(T)X(T)$
$\leq -\overline{E(T)} - \overline{G(T)} - s(T)q_{\gamma}^{-1}\overline{G(T)}(1+\gamma) - s(T)q_{\epsilon}^{-1}\overline{E(T)}(1+\epsilon)$
$- s(T)q_{\delta}^{-1}\overline{D(T)}(1+\delta)$,

(4) Capacity restraints

(4.01) $b(1)X(1) \leq b(1)(I+\alpha_0)\overline{X(0)}$,

(4.02) $b(t)X(t) - K(t) \leq 0$,

Table 2-5 (continued)

(5) Capital accounting relations

(5.01) $K(2) - Z(2) - R(2) \leq b(1)(I + \alpha_0)\overline{X(0)} - d\overline{D(2)}$,

(5.02) $K(t+1) - Z(t+1) - R(t+1) - K(t) \leq -d\overline{D(t+1)}$, for $t=2, \ldots, T-1$,

(5.03) $-Z(T+1) - R(T+1) - K(T) + b(T)q_{\emptyset}^{-1}(1+\emptyset)c(T)C(T) - b(T)q_{\mu}^{-1}(1+\mu)m'(T)X(T)$
$+ b(T)q_{\mu}^{-1}(1+\mu)M''(T) \leq -d\overline{D(T+1)} - b(T)q_{\gamma}^{-1}(1+\gamma)\overline{G(T)} - b(T)q_{\epsilon}^{-1}(1+\epsilon)\overline{E(T)}$
$- b(T)q_{\delta}^{-1}(1+\delta)\overline{D(T)}$,

(5.04) $-Z(T+2) - R(T+2) - Z(T+1) - R(T+1) - K(T) + b(T)q_{\emptyset}^{-1}(1+\emptyset)^2c(T)C(T)$
$- b(T)q_{\mu}^{-1}(1+\mu)^2m'(T)X(T) + b(T)q_{\mu}^{-1}(1+\mu)^2M''(T) \leq -d\overline{D(T+1)} - d\overline{D(T+2)}$
$- b(T)q_{\gamma}^{-1}(1+\gamma)^2\overline{G(T)} - b(T)q_{\epsilon}^{-1}(1+\epsilon)^2\overline{E(T)} - b(T)q_{\delta}^{-1}(1+\delta)^2\overline{D(T)}$,

(5.05) $-Z(T+3) - R(T+3) - Z(T+2) - R(T+2) - Z(T+1) - R(T+1) - K(T)$
$+ b(T)q_{\emptyset}^{-1}(1+\emptyset)^3c(T)C(T) - b(T)q_{\mu}^{-1}(1+\mu)^3m'(T)X(T) + b(T)q_{\mu}^{-1}(1+\mu)^3M''(T)$
$\leq -d\overline{D(T+1)} - d\overline{D(T+2)} - d\overline{D(T+3)} - b(T)q_{\gamma}^{-1}(1+\gamma)^3\overline{G(T)} - b(T)q_{\epsilon}^{-1}(1+\epsilon)^3\overline{E(T)}$
$- b(T)q_{\delta}^{-1}(1+\delta)^3\overline{D(T)}$,

(6) Restoration ceilings

(6.0) $R(t) \leq d\overline{D(t)}$, for $t=2, \ldots, T+3$,

(7) Balance of payments constraints

(7.0) $\mathcal{U}m'(t)X(t) + \mathcal{U}M''(t) \leq \overline{A(t)} + \mathcal{U}\overline{E(t)}$, for $t=1, \ldots, T$,

(8) Competitive import ceilings

(8.0) $[m''(t)]^{-1}M''(t) + \mathcal{U}m'(t)X(t) \leq \overline{A(t)} + \mathcal{U}\overline{E(t)}$, for $t=1, \ldots, T$,

(9) Initial capital in process restraints

(9.01) $Z(2) + R(2) \leq b\alpha(I + \alpha_0)\overline{X(0)} + d\overline{D(2)}$,

(9.02) $Z(3) + R(3) \leq b\alpha(I + \alpha_0)^2\overline{X(0)} + d\overline{D(3)}$.

TABLE 2—6

TABLEAU FOR THE TRANSIT MODEL

Constraints \ Variables		X(1)	C(1)	M"(1)	X(2)	C(2)	M"(2)	K(2)	Z(2)	R(2)	X(3)	C(3)	M"(3)	K(3)	Z(3)	R(3)	X(4)	C(4)
(1) Objective			1.0			$(1+w)^{-1}$						$(1+w)^{-2}$						$(1+w)^{-3}$
(2) Consumption Growth Constraints	1		-1															
	2		$(1+\rho)$			-1												
	3					$(1+\rho)$						-1						
	4											$(1+\rho)$						-1
	5																	$(1+\rho)$
(3) Distribution Relations	1	[a-l-m']	[c]	-[1]	[s]				[p']	[r"][d]$^{-1}$					[p"]	[r"][d]$^{-1}$		
	2				[a-l-m'-s]	[c]	-[1]				[s]				[p']	[r'][d]$^{-1}$		
	3										[a-l-m'-s]	[c]	-[1]				[s]	
	4																[r'-l-m'-s]	[c]
	5																	
(4) Capacity Restraints	1	[b]																
	2				[b]			-[1]										
	3										[b]			-[1]				
	4																[b]	
	5																	
(5) Capital Accounting Relations	1							[1]	-[1]	-[1]								
	2							-[1]						[1]	-[1]	-[1]		
	3													-[1]				
	4																	
	5																	
	6																	
	7																	
(5) Restoration Ceilings	2									[1]								
	3															[1]		
	4																	
	5																	
	6																	
	7																	
	8																	
(7) Foreign Trade Balance	1	um'		u														
	2				um'		u											
	3										um'		u					
	4																um'	
	5																	
(8) Competitive Import Ceilings	1	um'		[m"]$^{-1}$														
	2				um'		[m"]$^{-1}$											
	3										um'		[m"]$^{-1}$					
	4																um'	
	5																	
(9) Initial Capital in Process	2								[1]	[1]								
	3														[1]	[1]		

$s_\phi = s\,q_\phi^{-1}(1+\phi)c(T)$; $s_{\phi 2} = s\,q_\phi^{-1}(1+\phi)^2 c(T)$; $s_{\phi 3} = s\,q_\phi^{-1}(1+\phi)^3 c(T)$

$b_\phi = b\,q_\phi^{-1}(1+\phi)c(T)$; $b_{\phi 2} = b\,q_\phi^{-1}(1+\phi)^2 c(T)$; $b_{\phi 3} = b\,q_\phi^{-1}(1+\phi)^3 c(T)$

s_u, s_δ, s_ϵ, s_U etc. and b_u, b_δ, b_ϵ, b_U etc. are analogously defined.

M″(4)	K(4)	Z(4)	R(4)	X(5)	C(5)	M″(5)	K(5)	Z(5)	R(5)	Z(6)	R(6)	Z(7)	R(7)	Z(8)	R(8)	≷	R.H.S.
					$(1+w)^{-4}$												
																≤	$-(1+\rho(0))\overline{c(0)}$
																≤	0
																≤	0
																≤	0
																≤	0
		[p‴]	[r‴][d]$^{-1}$						[r‴][d]$^{-1}$							≤	$-\overline{E(1)}-\overline{G(1)}+s(1)[1+\epsilon_0]\overline{X(0)}$
		[p″]	[r″][d]$^{-1}$					[p‴]	[r″][d]$^{-1}$							≤	$-\overline{E(2)}-\overline{G(2)}$
		[p′]	[r′][d]$^{-1}$					[p″]	[r′][d]$^{-1}$	[p‴]	[r‴][d]$^{-1}$					≤	$-\overline{E(3)}-\overline{G(3)}$
−[1]				[s]				[p′]	[r′][d]$^{-1}$	[p″]	[r″][d]$^{-1}$	[p‴]	[r‴][d]$^{-1}$			≤	$-\overline{E(4)}-\overline{G(4)}$
				[a·l·m′·s·s$_\mu$m′]	[c+s$_\phi$]	[l+s$_\mu$]				[p′]	[r′][d]$^{-1}$	[p″]	[r″][d]$^{-1}$	[p‴]	[r‴][d]$^{-1}$	≤	$-\overline{E(5)}-\overline{G(5)}-s_\epsilon-s_u-s_\delta$
																≤	$[b][1+\epsilon_0]\ \overline{X(0)}$
																≤	0
																≤	0
	−[1]															≤	0
				[b]			−[1]									≤	0
																≤	$-[d]\overline{D(2)}+[b][1+\epsilon_0]\ \overline{X(0)}$
																≤	$-[d]\overline{D(3)}$
	[1]	−[1]	−[1]													≤	$-[d]\overline{D(4)}$
	−[1]						[1]	−[1]	−[1]							≤	$-[d]\overline{D(5)}$
				−[b$_\mu$m′]	[b$_\phi$]	[b$_\mu$]	−[1]			−[1]	−[1]					≤	$-[d]\overline{D(6)}-b_\epsilon-b_s-b_\delta$
				−[b$_{\mu 2}$m′]	[b$_{\phi 2}$]	[b$_{\mu 2}$]	−[1]			−[1]	−[1]	−[1]	−[1]			≤	$-[d]\overline{D(6)}-[d]\overline{D(7)}-b_{\epsilon 2}-b_{u 2}-b_{\delta 2}$
				−[b$_{\mu 3}$m′]	[b$_{\phi 3}$]	[b$_{\mu 3}$]	−[1]			−[1]	−[1]	−[1]	−[1]	−[1]	−[1]	≤	$-[d]\overline{D(6)}-[d]\overline{D(7)}-[d]\overline{D(8)}-b_{\epsilon 3}-b_{u 3}-b_{\delta 3}$
																≤	$[d]\overline{D(2)}$
																≤	$[d]\overline{D(3)}$
			[1]													≤	$[d]\overline{D(4)}$
									[1]							≤	$[d]\overline{D(5)}$
											[1]					≤	$[d]\overline{D(6)}$
													[1]			≤	$[d]\overline{D(7)}$
															[1]	≤	$[d]\overline{D(8)}$
																≤	$\overline{A(1)}+u\ \overline{E(1)}$
																≤	$\overline{A(2)}+u\ \overline{E(2)}$
																≤	$\overline{A(3)}+u\ \overline{E(3)}$
																≤	$\overline{A(4)}+u\ \overline{E(4)}$
u				um′		u										≤	$\overline{A(5)}+u\ \overline{E(5)}$
																≤	$\overline{A(1)}+u\ \overline{E(1)}$
																≤	$\overline{A(2)}+u\ \overline{E(2)}$
																≤	$\overline{A(3)}+u\ \overline{E(3)}$
																≤	$\overline{A(4)}+u\ \overline{E(4)}$
[m″]$^{-1}$				um′		[m″]$^{-1}$										≤	$\overline{A(5)}+u\ \overline{E(5)}$
																≤	$[d]\overline{D(2)}+[b][\epsilon_0][1+\epsilon_0]\overline{X(0)}$
																≤	$[d]\overline{D(3)}+[b][\epsilon_0][1+\epsilon_0]^2\overline{X(0)}$

During the plan period the level of imports, though not the composition, is effectively determined by the specification of the level of exports and net foreign capital available in each period and the balance of payments constraint. By the stipulation of a post-terminal growth rate for exports different from the post-terminal growth rate for imports, the trade gap can be made to decrease or increase in the post-terminal period. The post-terminal requirements for foreign aid, changes in gold reserves or debt repayment all can in this way be built into the solution of the model.

The statement of the Transit Model is now complete with the addition of its terminal conditions to the Basic Model core, but, in this case also, it cannot be assumed that a feasible solution always exists. As pointed out above, if the minimum initial level of consumption is not prescribed, the model has freedom to determine the level from which consumption growth will start while satisfying the growth constraints and achieving the terminal conditions. This will ordinarily be enough to guarantee a feasible solution. For example, zero aggregate consumption in each period would satisfy the monotonicity constraints and thus only enough capacity would be necessary in the plan and post-plan periods to satisfy the exogenous demands.

Having described the structure of the Target and Transit Models it is now possible to form a better overall appreciation of their strengths and their limitations.

2.4 Comments on the Structure of the Models

There is no difficulty in writing down analytical models which are more sophisticated and "realistic" than those presented above. The difficulties are in finding data with which to fill in the models, in being able to find solutions and in carrying out the computations. The models used here embody compromises on all accounts.

We believe that the principal limitations are the following:

(1) The utility function and the production functions are assumed to be linear.

(2) The objective function and the constraints do not embody all the relevant goals of development.

(3) Coefficients which are constant over time neglect changing technology and sectoral composition of output.

(4) The lag structure of investment is rigidly fixed.

(5) The treatment of imports provides only a small scope for the operation of comparative advantage.

(6) Labor and other non-capital factors are assumed adequate.

Since most of these limitations have been discussed above in the course of presenting the models' relationships we comment further only on those not previously treated explicitly.

First of all, no more than anyone else, do we believe that linear relationships are universally correct descriptions of technology and behavior. In a general sense non-linearities and externalities are at the heart of development economics. While they are ignored in the models they cannot be ignored in appraising them and their results. There are grave difficulties, analytical and informational, in embodying non-linearities

in the modes which have led us to avoid them. Literary discussions and simple models can help explore the general significance of non-linearities but do not lead to detailed, quantitative results. Linear approximations to non-linear relationships would, in some cases, be satisfactory devices but at this point limitations of information and computational capacity interfere. Models of the types presented here have relatively large computational requirements. If used in actual planning procedures, the costs of computation would be a small cost to bear but they are a real constraint in the present state of research. Likewise, data availabilities for an independent research project are different than they would be in an actual policy-making situation. Some information gaps are unavoidable, however, and planning commissions are no more likely to be able to fill them than are research institutes.

The production technology in these models is highly simplified. First of all, labor is neglected and fixed capital and intermediate inputs are the only requirements for outputs and these are specified by coefficients which are fixed. The coefficients do not vary with output and, thus, constant returns to scale are assumed. Moreover, they do not change with time, except insofar as they are made to do so exogenously, and thus have no "built-in" allowance for technological change. Taking up these limitations in order, it would have been possible to specify labor requirements by types and have these specifications and labor availabilities act as production constraints. A set of labor formation relationships would have to be developed and these, preferably, should embody some opportunities for substitution among skill categories. Except for the substitution features, the structures of the relationships would be a relatively

straightforward affair. Computation requirements would again increase. The greatest obstacles to this refinement would be in the difficulties in making provision for skill substitution and in the inadequacies of data. Labor skills at all levels have a variety of sources of which formal training may be relatively unimportant especially in the less-developed countries in which "on-the-job' training is probably a larger component of total education than is formal education. The ordinary type of educational statistics is not relevant and the necessary data are usually unavailable. Even casual observation suggests a wide range of relative intensities of use of labor of different skill levels in different countries. Engineer/worker and foreman/engineer ratios appear to vary considerably depending on relative wages, educational structures, level of industrialization and so on, but systematic data are lacking. Still there are countries in which the general availability of skills is so limited that to omit this type of constraint, even though it were roughly approximated, would be to overlook the core of the development problem. This does not appear to us to be the case in India, however. While the supply of professional and sub-professional skills could not be said to be "adequate" there is a relatively large cadre of such skills and a large and growing educational system. Though bottlenecks may exist, for example, in the number of persons competent to initiate and manage large new enterprises, public and private, that type of bottleneck is not easily brought within the framework of models such as those presented here.

It does not require much imagination to think of other ways of improving the structure of technology represented in the model. For

example, though capital is a composite good in each sector, there is only one type of capital, i.e. one composition for each sector. Yet agriculture requires implements and wells, etc., and not necessarily in fixed proportions. With more information and disaggregation various types of capital, each with its own commodity composition could be stipulated as required in the different sectors and capital formation relations written for each. The computational burden would be increased by the additional detail and the need for permitting substitution among types of capital.

Technological change must remain exogenously specified. To the extent that there is advance knowledge, as, for example, from project plans for a new plant, the new coefficients can be embodied. Otherwise, at this stage of our knowledge formal planning models are no better and no worse in taking technological change into account than other techniques.

The capital formation and capital accounting relationships in the model could be easily improved with additional data and at the cost of additional computation. The gestation lag might be extended beyond three periods and some flexibility introduced. It was pointed out above that the present formulation forces a rigid sequence on capital formation whereas in practice there is a certain amount of choice. Even if this choice is not exercised to any great extent its potential significance could be demonstrated by a more flexible procedure. However, the flexibility in the lag structure would be important only during the initial years of a plan when some of the capital goods producing sectors may have idle capacity.

At this point we can make our obeisance to problems associated with aggregation. They are particularly difficult in the analysis of developing countries as the composition of output in many sectors will often be changing rapidly. Still we have nothing new to offer on the theoretical issues or on practical procedures.

2.5 The Solutions of the Models

A solution determines the unknown variables of the model. These unknowns are the gross domestic outputs X(t), the level of aggregate consumption C(t), competitive imports M"(t), capital stocks K(t), new capital Z(t) and restored capacity R(t).

For any set of values of the parameters, a solution, if it exists, will be a point in consumption space defined by the intersection of the binding constraints. Variation of the relative weights in the objective function on consumption in each period will move the solution to a different point on the production feasibility surface. Variation of the post-terminal conditions will change the solution by shifting the feasibility surface. Likewise, changes in the production parameters will change the production feasibility surface itself and consequently the value of the maximand for any given objective function. For each value of the maximand there is a specific allocation of resources and outputs in each period. Thus, for each solution it is possible to generate for each period a detailed list of gross output levels, imports and final demands, inter-industry transactions, investment allocations and capital stock uses which will sustain the maximand. This sectoral and temporal detail along with the associated set of national income accounts facilitate overall appraisal of the implications of each solution.

2.6 The Shadow Prices

Corresponding to the allocations of "physical quantities" the model's solution generates a set of shadow prices related to each of the constraints. These shadow prices are the variables of the minimizing valuation problem which is the dual of the maximizing problem. In the minimizing problem prices are found for the scarce resources, in this case the sectoral capacities and foreign exchange, which exhaust the value of the total product and minimize the cost of production within the behavioral as well as technological constraints. These shadow prices require careful use and interpretation especially since there may be a tendency to identify them either with "real world" prices or with the prices in some other ideal competitive system which has a different technology and set of constraints than those of the models described above. There are, for example, constraints on the rate of growth of consumption which are behavioral or political constraints. Just as the entire solution must adjust itself to these constraints, so must all the shadow prices. For example, if the consumption monotonicity constraint is binding in any period, it means that the value of the maximand could be increased somewhat if consumption in that period were allowed to drop. Consumption in some other period would rise by more than an equivalent amount. The resource allocations would then change and other shadow prices on output, capital, etc. would also shift.

From the solution of the model and its dual the following resource values or "shadow prices" are determined:

$V_{X(t)}$ = Vector of shadow prices of X(t) obtained as values associated with the distribution restraints;

$V_{K(t)}$ = Vector of shadow rentals of capital K(t) obtained as values associated with the capacity constraints;

$V_{Z(t)}$ = Vector of shadow prices of new capital stock Z(t) obtained as values associated with the capital accounting relations;

$V_{CR(t)}$ = Shadow price of the consumption growth constraints;

$V_{FX(t)}$ = Shadow price associated with the foreign exchange balance requirements;

$V_{M''C(t)}$ = Vector of shadow prices corresponding to the ceilings imposed on the competitive imports;

$V_{R(t)}$ = Vector of shadow prices of restorable capacity obtained as values associated with the restoration ceilings;

$V_{IK(t)}$ = Vector of shadow prices of initial capital in process obtained as values associated with initial capital in process constraints.

The meaning of a shadow price can be appreciated properly by referring to the corresponding constraint in the dual problem. The constraints of the dual can be read from the tableau of Table 2-4 for the Target Model and from Table 2-6 for the Transit Model by reading down the columns.

The prices associated with the distribution relations are the shadow prices of the outputs. From Table 2-4 looking down the column of, say X(2), we can write down the dual relation as follows

$$s^T(2)[V_{X_1} - V_{X(2)}] + [a-m]^T V_{X(2)} + bV_{K(2)} + m'V_{FX(2)} + m'V_{M''C(2)} - V_{X(2)} \geq 0 \;;$$

$$\text{i.e.} \left\{\begin{matrix}\text{Value of}\\ \text{changes in}\\ \text{inventories}\\ \text{in the first}\\ \text{period}\end{matrix}\right\} + \left\{\begin{matrix}\text{Value of}\\ \text{indirect}\\ \text{inputs}\\ \text{for}\\ X(2)\end{matrix}\right\} + \left\{\begin{matrix}\text{Rental}\\ \text{of}\\ \text{capital}\\ \text{to produce}\\ X(2)\end{matrix}\right\} + \left\{\begin{matrix}\text{Value}\\ \text{of}\\ \text{imported}\\ \text{inputs}\end{matrix}\right\} + \left\{\begin{matrix}\text{Penalty}\\ \text{price for}\\ \text{competitive}\\ \text{import}\\ \text{ceilings}\end{matrix}\right\} - \left\{\begin{matrix}\text{Shadow}\\ \text{price}\\ \text{of}\\ X(2)\end{matrix}\right\} \geq 0.$$ [1]

It should be noted that the constraints corresponding to X(1) are different from the above in that they do not have any inventory term. For the Transit Model from Table 2-6 it is seen that the restraints which correspond to X(5) the outputs of terminal years include values of post-terminal capital stocks. This is so because in the Transit Model the post-terminal stocks are dependent on the levels of non-competitive imports M'(5) and hence on X(5).

The prices associated with the capacity restraints are the shadow rentals of capital in the period of the restraint. For example, column K(2) in Table 2-4 or 2-6 gives us

$$-V_{K(2)} + V_{Z(1)} - V_{Z(2)} \geq 0 \;:$$

$$\text{i.e.} \quad -\left\{\begin{matrix}\text{Shadow}\\ \text{rent}\\ \text{of}\\ \text{capital}\\ \text{in period 2}\end{matrix}\right\} + \left\{\begin{matrix}\text{Value}\\ \text{of}\\ \text{capital}\\ \text{in}\\ \text{period 1}\end{matrix}\right\} - \left\{\begin{matrix}\text{Value}\\ \text{of}\\ \text{capital}\\ \text{in}\\ \text{period 2}\end{matrix}\right\} \geq 0.$$

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1 Superscript T indicates the transpose of the matrix.

Since capital services are in perfectly inelastic supply in any one period the shadow prices on these services are either positive, if all the capacity is in use, or zero, if it is to any degree in excess supply.

Since foreign exchange can always be used indirectly to increase the maximand it should always have a positive shadow price. The shadow price on the balance of payments constraint reflects not only the shadow prices of imports but also the shadow prices on the constraints on the use of foreign exchange for competitive imports. When they bind these constraints may prevent the use of foreign exchange in the sectors in which it would contribute most to the maximand. The shadow prices on the competitive import constraints indicate the value in terms of the maximand of an additional unit of foreign exchange into the particular use.

The relation between the shadow prices on the foreign exchange balance constraints, on output and on competitive import ceilings can be obtained from Table 2-4 by looking down the column M"(t); e.g. for M"(2) we have

$$-V_{X(2)} + V_{FX(2)} + [m'']^{-1} V_{M''C(2)} \geq 0 \; ;$$

$$\text{or, } -\left\{\begin{matrix}\text{Shadow}\\ \text{price}\\ \text{of}\\ \text{output}\\ X(2)\end{matrix}\right\} + \left\{\begin{matrix}\text{Shadow}\\ \text{price}\\ \text{on}\\ \text{foreign}\\ \text{exchange}\\ \text{balance}\end{matrix}\right\} + \left\{\begin{matrix}\text{Shadow}\\ \text{price}\\ \text{of}\\ \text{import}\\ M''(2)\end{matrix}\right\} \geq 0.$$

The shadow price on the balance of payments constraints should not be identified with what is usually meant by the shadow price of foreign exchange. First of all, it is itself a shadow price constrained by all

the other relationships and, particularly, those on the use of foreign exchange for competitive imports. Secondly, by no means all of the supply and demand forces which in reality affect the foreign exchange rate are taken into account in the model. The shadow price also reflects the availability of the stipulated foreign aid and private capital flows from all sources. Thus, there is no easy translation from this shadow price on foreign resources to the shadow price of the rupee against the dollar.

The shadow price of consumption is, of course, the weight of C(t) in the objective function namely $(1+w)^{1-t}$ It is not simply the value of the components that make up the composite consumption but is affected by the consumption growth constraints. From the column of C(2) in Table 2.4 we have

$$-V_{CR(2)} + (1+\rho)V_{CR(3)} + \{3\}^T V_{X(2)} \geq (1+w)^{-1} .$$

$$\text{or, } -\left\{\begin{array}{c}\text{Value of}\\ \text{consumption toward}\\ \text{meeting consumption}\\ \text{growth constraint}\\ \text{in period (2)}\end{array}\right\} + \left\{\begin{array}{c}\text{Value of}\\ \text{additional}\\ \text{consumption}\\ \text{which will have}\\ \text{to be provided}\\ \text{in period (3)}\\ \text{to meet the}\\ \text{consumption}\\ \text{growth}\\ \text{constraint}\\ \text{in period (2)}\end{array}\right\} - \left\{\begin{array}{c}\text{Value}\\ \text{of}\\ \text{inputs to}\\ \text{consumption}\\ \text{in (2)}\end{array}\right\} \geq \left\{\begin{array}{c}\text{Discount}\\ \text{value}\\ \text{of}\\ \text{consumption}\\ \text{C(2)}\end{array}\right\}$$

It may be seen from this that, if consumption in the objective function is discounted, the shadow prices on output also embody the discount rate.

The shadow price of new investment in a sector does not reflect the usefulness of the capacity over the entire future but instead it reflects the cost of the new investment in terms of discounted consumption over the plan period. It should be noted, however, that all the shadow prices are affected by the post-terminal conditions imposed including those of the inputs required to produce the new capital. The dual constraint corresponding to column, say Z(4), from Table 2-4 is as follows:

$$\underbrace{[p']^T V_{X(3)} + [P'']^T V_{X(2)} + [p''']^T V_{X(1)}}_{\{\text{Cost of inputs}\}} - V_{Z(3)} \geq 0 ,$$

or

$$\{\text{Cost of inputs}\} - \left\{\begin{matrix}\text{Value}\\ \text{of}\\ \text{new}\\ \text{capital}\end{matrix}\right\} \geq 0 .$$

The shadow prices are no worse and no better a part of the solution than are the real variables. They are an intrinsic aspect of the solution and if one accepts the solution of the allocation problem one has to accept the meaning of the associated shadow prices. In this context two related questions arise as to the "usefulness" of shadow prices. First, can these shadow prices be used in project evaluation? Second, would the enforcement of these shadow prices by a central authority lead an otherwise uncontrolled economy to the optimum allocation? We will take these questions in turn.

2.6.1 Use of the Shadow Prices in Project Evaluation

The shadow prices can be used for project evaluation provided the following three conditions are met:

(1) All the shadow prices are used in the evaluation.

(2) The size of the project being considered does not violate the linearity and divisibility assumptions of the model. This may happen if the project is so small that different technical coefficients do not materially alter the technical coefficients of the sector to which it belongs. On the other hand a project which has the same technical coefficients can be as big as the sector itself and may still not violate the linearity assumptions.[1]

(3) The model includes all the restraints and goals of the society. If objectives are left out which are nonetheless considered practically important, then the solution of the model is not the true optimum solution with respect to the larger set of goals but is just a point on the feasibility surface. The prices then correspond to this efficient point and not to the true optimum point.

2.6.2 The Shadow Prices and Decentralization

The enforcement of the shadow prices by a central authority would not in general lead to the optimum allocation because of the following reasons:

(1) The real world is neither linear nor divisible in all sectors.

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1 In this latter case, the project would be acceptable but, perhaps, less so than some alternative project. The alternatives would have to be investigated by rerunning the model and allowing it to choose the optimum technique.

(2) Everyone may not have the same objective function of maximizing consumption over five years discounted in the specific manner. A different objective or a different discount rate would affect the choice of investments and the efficient projects may not be selected.

(3) The dynamic nature of the economy requires that a complete year by year price specification be made in advance and that this specification be credible. Even then the existence of an equilibrium is not assured and oscillations may result.[1] For example, if over investment occurs in a sector, it is realized only at the end of the gestation period when again everyone would want to disinvest.

(4) Finally, the non-economic constraints may not reflect the goals of individual profit maximizing competitors and the corresponding constraint prices may not be enforceable. For example, consumption growth constraints can be imposed by an expenditure tax on consumption in those years when the solution indicates that the constraints are binding. On the other hand competitive import ceilings which may reflect the policy of import substitution or national self-sufficiency are hard to impose by prices alone without actually specifying the levels of imports.

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1 See K. Arrow and G. Debreu, "Existence of an Equilibrium for a Competitive Economy," Econometrica, 22:265-90; July, 1954.

In describing the models we have tried to present their economic rationale as well as their formal structure to make clear their weaknesses as well as strengths. The final test of any method is not just its analytical sophistication but its relative effectiveness in dealing with the important questions. A planning framework with an elaborate treatment of relatively minor problems may not be as useful as a cruder approach to the central issues. Some appreciation of the usefulness of the models is possible based on the discussion so far. This appreciation can be improved by examining the results of applying the models and it is to that to which we shall turn.

CHAPTER 3

DATA FOR THE THIRD AND FOURTH FIVE YEAR PLAN PERIODS

The firefly seems a fire, the sky looks flat;
Yet sky and fly are neither this nor that.
The true seem often false, the false often true;
Appearances deceive, so think it through.

--The Panchatantra

3.1 Data Requirements

Once the theoretical structure of the models has been specified it is possible to describe the kind of information necessary to fill in that structure. Perhaps, then, with imagination and foresight every real difficulty in actually developing the data could be foreseen. It has been our experience, however, that our appreciation of the difficulties in the empirical problems has increased in the process of confronting them. The process has been a tedious one, however, and we shall present only the end results.[1]

The only material used has been that in generally available public documents. On the other hand, we have modified and extrapolated these data when it appeared to us that there was a reasonable basis for doing so. We have proceeded with inadequate information when we believed that there was in fact a basis for developing improved data if their usefulness could be demonstrated. For example, at the outset of this project only one ten-year old input-output table existed for India. After extensive investigation of various sources it was concluded that there was ample basis for the preparation of a new and substantially improved inter-industry flow matrix. At the stage of final computation we were able to use a reasonably current and improved input-output matrix. Since this input-output table and most other originally available data were estimated in 1959-60 prices, this price level was maintained throughout in all estimations and projections.

In order to apply the models described in the previous chapter data are required for defining the technology of production and also to specify the various exogenous demands. On the production side the following information is needed for each period:

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1 Data tables are presented separately in the accompanying volume.

(1) a(t), inter-industry flow coefficient matrix a

(2) s(t), stock-flow matrix,

(3) b, diagonal matrix of aggregate capital coefficients

and (4) p, capital proportion matrix

(5) p', p'' & p''', proportion matrices for investment lags

(6) m', diagonal matrix of non-competitive import coefficients.

To specify the demands for output, the following have to be estimated for each period:

(7) c(t), vector of consumption coefficients,

(8) D(t), vector of the fixed capital which (completely) depreciates in period (t),

(9) r, composition matrix for the depreciated capital,

(10) $\overline{E(t)}$, vector of exports,

(11) $\overline{G(t)}$, vector of government consumption,

(12) $\overline{A(t)}$, net foreign capital inflow,

(13) δ, ϵ, γ post-terminal growth rates for D, E and G.

Initial and terminal conditions are prescribed by the following:

(14) $\overline{X(0)}$, vector of domestic output levels in the pre-plan period. This is used to estimate $\overline{K(1)}$.

(15) α_o, diagonal matrix of implicit yearly growth rates projected for the early periods of the plan in the pre-plan years. α_o along with $\overline{X(0)}$ is used to determine the initial capital stocks and the initial capital in process.

(16) $\overline{X(T)}$, α_T vector of domestic output levels for the target year T, $\overline{X(T)}$, and matrix of projected post-terminal growth rates, α_T, are used to determine the terminal capital stocks and the terminal capital in process for the Target Model.

(17) ϕ, μ, post-terminal growth rates for consumption and imports respectively. $\phi, \mu, \delta, \epsilon$ and γ are used to determine the post-terminal capital stocks for the Transit Model.

Policy variables to be decided upon by the planner are the following:

(18) m'', competitive import coefficients for exchange allocation ceilings

(19) $\rho(t)$, minimum growth rate of consumption in period t

3.2 Description of Sectors

The sectoral classification had to be decided on the basis of the input-output tables available. At the start of the project in 1963 the most recent input-output table available was for 1955-56 and was on a fifty-sector basis. It was compiled at the Indian Statistical Institute by Ashish Chakravarti. An attempted computation on a fifty-sector basis using the 1955-56 I.S.I. input-output table demonstrated that it would exceed the amount of computational capacity at our disposal taking into account our experimental purposes which include calculation of a number of alternative solutions. Some rough calculations indicated that computations on the basis of a modified thirty-two sector 1959-60 I.S.I. table would again be outside the acceptable computation time. Further aggregation was necessary. Unfortunately, aggregation could not be carried out in a way which would be certain to satisfy the theoretical criteria for avoiding bias.[1] This is due partly to lack of the empirical knowledge which the criteria require and partly because of the previous aggregation

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1 For a survey of aggregation problems in production data, see A. A. Waters, "Production and Cost Functions: An Econometric Survey," Econometrica, Vol. 31, No. 1-2, Jan.-April, 1963, pp. 5-11.

which had undoubtedly been done on an unsatisfactory basis. In this instance the thirty-two sectors already represent a high degree of aggregation and lacking a full description of the tables we were, to a substantial extent, ignorant of the detailed sectoral composition. Experimentation with various classification systems led us to settle on an eleven sector level of detail in order to achieve computational convenience. Table 3-1 indicates the manner in which the sectors were aggregated.

3.3 Production Data

As indicated in the description of the models the Leontief input-output assumptions of "fixed coefficients" of production have been adopted. The production data with which the models are provided are a set of ratios for each sector. These ratios indicate input requirements per unit of output. The ratios can be changed exogenously from period to period and from one solution to the next. However, the Target and Transit Models are not provided with technological alternatives. The general structure and logic of input-output tables have been discussed in detail elsewhere[1] so we shall not review that material. Likewise, since we utilize only secondary sources and published information we shall not repeat the detailed descriptions of the data which exist in the original documents. The following discussion will be limited to brief accounts of the data used and to explanations of the adjustments which have been made.

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1 W. Leontief and others, Studies in the Structure of the American Economy, New York, 1953, and H. B. Chenery and P. G. Clark, Interindustry Economics, New York, 1959.

3.3.1 Inter-Industry Flow Coefficient Matrices a(t)

In early 1964, two new Indian input-output tables became available for 1959-60. One was prepared in the Indian Statistical Institute in Delhi under the direction of A. Rudhra and with the cooperation of A. S. Manne of Stanford University, who was then a member of the India Project of the Center for International Studies, M.I.T. The second table was estimated in the Inter-industry Study Group of the Planning Commission under the direction of K. S. Khrisnaswamy of the Economic Growth Section. These tables were prepared for somewhat different purposes and differ with respect to a number of features. Lacking access to details of their construction it was not possible to reconcile the differences in the tables. In most cases, however, the variations do not appear to represent different estimates of the same concept but rather somewhat different concepts. Inasmuch as somewhat more information as well as other supporting data were available for the I.S.I. table as compared to the Inter-industry Study Group table the former has been used in the computations. The I.S.G. table has been used, however, to supply information not in the I.S.I. table on the distribution of inputs in the transport sector and the use of imports.

The 1959-60 I.S.I. table which we use is basically that presented in Notes on Perspective of Development, India: 1960-61 to 1975-76[1] and is shown in Table 3-2. It is a thirty sector table with inputs valued at producers' prices. The final uses of output are for the Household, Government and Export sectors, for Inventory Stocks, Gross Fixed Capital Formation and Others, a miscellaneous sector. Total domestic production

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1 Perspective Planning Division, Planning Commission, Government of India, April, 1964, pp. 183-187.

is obtained after subtracting Imports. In addition to the inputs of the intermediate producing sectors, Wages and Salaries, Gross Profit and Margins are distinguished. The latter includes wholesale and retail trade margins and indirect taxes and subsidies.

In the I.S.I. table only five sectors produce fixed capital: the urban and rural construction sectors and the electrical, transport and non-electrical equipment sectors. Such industries as cement, iron and steel and non-ferrous metals, rather than supplying outputs directly for fixed capital formation deliver to the construction sectors which in this table are processing rather than service industries. They receive inputs, process them and deliver fixed capital.

Inasmuch as the purpose in the experiments with empirical information is the analysis and demonstration of generally applicable techniques, the following modifications are made in the I.S.I. table. (a) In several sectors there is a negative input entered in the miscellaneous "Others" sector as an aggregate correction to over-estimation of inputs to other sectors. Such a negative input is eliminated by allocating it along the row among the deliveries of the sector using the proportions of the positive deliveries as a guide so that

$$a_{ij}^{new} = a_{ij} - \tilde{a}_i \frac{a_{ij}}{\sum_{j=1}^{30} a_{ij}}$$

where $\tilde{a}_i$ is the negative input from the ith sector. (b) The undistributed inputs of the rail and motor transport sectors were allocated using the proportions from the I.S.G. table. (c) A major change made in the I.S.I. table was the creation of a Residential Housing sector which provides

rental services. This sector constitutes approximately seven per cent of the consumer budget; it is also the sector with largest capital-output ratio. Initial experiments with the 1955-56 I.S.I. table reinforced the view suggested by these characteristics that over-all results would be sensitive to the size and growth rate of this sector. It was, therefore, decided to isolate Residential Housing from the miscellaneous "Others" sector. In order to construct a Residential Property row it was assumed that this sector delivers only to Private Consumption and the amount of the delivery was the 520 crores of rupees estimated as the output of the sector in the official national income accounts for 1959-1960. This amount was subtracted from the delivery of the Others sector to Private Consumption. The Residential Housing column was formed by allocating the row total among the input sectors using the relevant coefficients of the 1955-56 I.S.I. input-output table. (d) The Margins sector was made into a source of intermediate inputs rather than being treated, like Wages and Salaries, as payments to a primary factor. This was done to conform to the usual practice for wholesale and retail trade. Lacking any other basis for establishing an empirical relation it would, in any case, have been necessary to relate outputs of the trade sectors to other sectors by fixed coefficients. Table 3-3 presents the modified 1959-60 I.S.I. table now on a thirty-two sector basis. Tables 3-4 and 3-5 present the matrix of inter-industry coefficients aggregated to eleven sectors using as weights the gross domestic outputs in 1960-61 and projected gross domestic outputs in 1965-66 respectively. The former is used for the Third Plan period and the latter for the Fourth Plan period.

3.3.2 Stock-flow Coefficients

The patterns of inventory-holding in the less-developed areas have not been studied intensively and relatively little empirical information is available. Such information is notoriously difficult to collect and the statistical reporting systems of these areas have not been able to cover this aspect of investment in a thorough manner. Some data which do exist suggest that inventory accumulation may be a relatively more significant part of total investment in the less-developed areas. The limitations of transport and communications and other uncertainties associated with deliveries would contribute to such a pattern.

The inventory coefficient s_j, the ratio of total inventories held by sector j to annual output of the sector j, is calculated from two sources: (1) Notes on Perspective of Development, Table (M) and (2) Annual Survey of Industries, 1960, CSO, India. 1960-61 output levels were used as weights in aggregating for the Third Plan period and projected output levels for 1965-66 for the Fourth Plan period. For those sectors for which information was available from both sources the values from the P.P.D., Notes are assumed to supercede those from the Annual Survey except in Transport Equipment, Cement and Cotton and Other Textiles. The P.P.D., Notes were not comprehensive so "typical" coefficients had to be used. Neither source covered all sectors and in the remaining sectors the coefficients are simply guessed. These guesses are, however, based on two estimates, one made by A. K. Sen and the other by A. Chakravarti. Table 3-6 shows the aggregate inventory/output coefficients. From these aggregate coefficients an inventory/output coefficient matrix is constructed. The aggregate inventory output ratio in each sector is

distributed along a column in the proportions of the storable elements of the input column in the corresponding a matrix. Before doing this, however, the coefficients of the Other and Margin sectors were eliminated on the grounds that the contribution of this sector was so miscellaneous that it would be difficult to know what was in fact storable.

Tables 3-7 and 3-8 present the inventory/output coefficient matrices for the Third and Fourth Plan periods respectively.

In carrying out calculations for alternative values of the parameters several of the larger inventory coefficients were reduced in order to provide tests of sensitivity of the results to changes which reduce the investment requirements for growth. In the alternative set, the aggregate inventory coefficients are changed as follows: in Agriculture from 0.393 to 0.131; in Food, Clothing and Leather from 0.361 to 0.181; in Chemicals from 0.528 to 0.259. This alternative set of inventory coefficients is also shown in Table 3-6. A corresponding s matrix of inventory/output coefficients is created in the same manner as described above for the matrices in Tables 3-7 and 3-8.

3.3.3 Fixed Capital Formation and Output

Much of what was said about the current flow matrices by way of qualification is applicable to the capital formation relations as well so the remarks on aggregation problems and technological change will not be repeated.

As pointed out previously there is no detailed accounting of capital stock by "vintages" in the model. Therefore, it is necessary to assume the same capital/output ratio for all past accumulations of fixed capital as well as for new investment. If information were available for

the projections it would be possible to change the ratios exogenously but it would be more of an improvement to distinguish capital vintages. The ratios estimated are intended to be marginal rather than average capital coefficients. This is the most common type of data available and interest centers on the new investments required during a plan period. Since these coefficients are used to estimate the initial capital stock from output levels, rather than vice-versa, the capital stock levels are scaled up or down from their "true" levels depending on the unknown relation between the average and marginal coefficients. This, in turn, may throw off the capital accounting relationships somewhat since depreciation is based on historical estimates of capital formation.

A substantial amount of information on capital output ratios exists for the Indian economy which has not yet been fully utilized. For modern industry, in particular the data potentially available are quite comprehensive and even for the traditional sectors and agriculture a good deal of partial and sample survey data exist. In these latter sectors, however, the relation of capital accumulation to capacity changes may be less reliable than in industry and certainly warrants much more investigation. The estimation procedure followed was to establish aggregate capital-output ratios for each sector and then to determine the relative contribution of each of the capital-supplying sectors and finally to distribute this over the entire gestation period. This was first done independently using a wide variety of sources of information. The estimation procedures were not sophisticated, and there were never enough observations of the same quality to warrant the use of econometric methods based on the assumption of stochastic processes. In general an

attempt was made to rely almost entirely on Indian data to estimate the aggregate capital-output ratios.

In 1964 a matrix of capital coefficients was estimated in the Indian Statistical Institute, New Delhi by Vinod Prakash. These estimates also give the breakdown of capital coefficients in four types of capital, urban construction, rural construction, transport equipment and other equipment. The estimates are based on numerous studies "released or undertaken by the various official and non-official agencies." The Prakash matrix is used as the basis of most of the computations as the most recently available authoritative estimates. Since the coefficients are in producers' prices, they are modified to include trade margins which are assumed to be 13% of the equipment portion of capital in the sector. The aggregate capital coefficients and their composition are shown in Table 3-9. The eleven sector coefficients are aggregated using as weights the capital stocks as implied by these coefficients and by the output levels in 1960-61 and 1965-66 in Tables 3-10 and 3-11 which also show the proportion matrices p implicit in these coefficients for the Third and Fourth Plan periods respectively.

The set of capital-coefficients taken from I.S.I. sources will be referred to as the "Reference" set. They appear to us to be reasonable but moderate. In sensitivity tests the coefficient in Agriculture is reduced from 1.5 to 1.0 and the coefficient in Housing is reduced from 10.0 to 7.5. These alternate capital coefficients are also shown in Table 3-9 as 'lower' set.

The capital-output ratio in transport for the Third and Fourth Plan periods is relatively low as the Prakash assumption was adopted that no substantial additional construction would be necessary during these

periods in these sectors. The capital coefficient in Housing, which is the highest, depends on the relative weights of urban and rural construction in total output which was not known to us. This number was among those changed in some of the sensitivity tests. No procedure for exogenously changing the capital formation relations was available to us which would reflect changing technology and industrial composition and be clearly superior to treating these as if they were constant in these pilot computations. So they were treated in this way but changed parametrically in some alternative solutions.

3.3.4 Lag Proportion Matrices

The next step in data preparation was the disaggregation of the capital formation by periods. The existence of gestation periods of varying lengths is a major source of the problems of coordinating the growth of different sectors in development programs. In addition, since in the less-developed regions delays in making capital effective have a particularly high cost it is important to be able to analyze such delays.

Published empirical information about the gestation periods of capital projects is relatively scarce for developed as well as for less-developed regions. There is a substantial body of informal comment which holds that gestation periods in the less-developed countries are quite different from practices prevailing in the developed areas. Although the existence of several studies of the time patterns of capital creation indicates the feasibility of such investigations, secondary sources are completely inadequate for this purpose and no independent estimation was attempted.

We adopt a simple pattern to represent the gestation process which could be easily modified as more information became available. It is assumed that the construction component of investment required to achieve an increment of capacity in period t has to be made in three equal installments over the three preceding periods, t-1, t-2 and t-3. For the equipment component of investment it is assumed that one-half of the total requirements has to be provided in each of two periods preceding the period in which capacity was to become effective. With these assumptions the matrices showing proportions of total requirements of each sector in periods t-1, t-2 and t-3 for capacity which will mature in period t are estimated for India for the 1960's as shown in Tables 3-12 and 3-13 for the Third and and Fourth Plans respectively.

Again for sensitivity tests the gestation lag structure is changed in a manner which would facilitate the adjustments of the system. The alternative lag-proportion matrices are based on our judgment as to the potential for reducing the time lag in capital creation in some sectors. The investment lag in Construction and Others and Margin sectors is reduced to one year. In Mining and Metals and in Electricity, the three years gestation lags are kept. In all remaining sectors the lag is reduced to two years. These matrices are shown in Table 3-14 as the "Alternative Lag Proportion Matrices."

3.3.5 Imports

The only readily available information on non-competitive imports as defined in Chapter 2 was that presented in the Inter-industry Group's transactions matrix. In a single column it estimated that quantity of imports which, though classifiable in one of the grossly defined producing sectors, could be considered as non-competitive. A separate row for all

non-competitive imports allocated them to each producing sector. Since this treatment went far in blurring the desired distinction in any case, it was decided to adjust the matrix by absorbing the non-competitive import row into the body of the transactions matrix as if they were competitive imports. The non-competitive imports are treated as fixed fractions of the total output of the sectors in which they were assigned. The ratios of non-competitive imports to output were calculated from the Inter-industry Group's input-output matrix and used as non-competitive import coefficients. Table 3-13 lists these coefficients by sector.

As noted previously, ceilings are set in the models on the use in each sector of the foreign exchange left over after the satisfaction of non-competitive import needs. These ceilings are in the form of ratios of uncommitted foreign exchange. The ratios are based on the import information in the I.S.I. and Inter-industry Group input-output tables with some adjustments based on guesses as to the sectors in which government policy would be more or less restrictive in permitting import substitution for domestic production. These ratios are also shown in Table 3-15.

In the P.P.D., Notes a strong emphasis is placed on import substitution aspect of the Fourth Plan Targets. Sectoral projections of imports for 1965-66 and 1970-71 are also given. However, this information is not sufficient to generate the non-competitive import coefficients that are presumed for 1970-71. In some solutions to investigate the effects of import substitution the non-competitive import coefficients are reduced from year to year. The coefficients assumed for this purpose are shown in Table 3-16.

3.4 Demand Data

3.4.1 Depreciation

The operating lifetimes of many types of capital are twenty to twenty-five years or more which is substantially longer than the planning horizon of the short-term models. Given such life spans and the "one hoss shay" pattern of capital decay, depreciation is exogenous to these models, being determined by the investment which took place in the years previous to the start of the plan period. The problem is thus transformed into one of estimating investment during the early post war years for which relatively little statistical information exists.

An estimate of depreciating capital is made as follows.

(1) Lifetimes of twenty-five and thirty-three years are assumed for equipment and construction respectively.

(2) We assume further that prior to 1951 a steady state prevailed in which all extensive magnitudes grow at the same rate of 1.5% per annum, the rate of growth of population. Then depreciating capital in t, D(t) is given by

$$D(t) = D(0)e^{0.015t}$$

(3) The Central Statistical Organisation has estimated that in 1948-49 total replacement was Rs. 611.0 crores in current prices. This has to be converted to 1959-60 prices. For this we have the C.S.O. estimates in current prices of gross investments in 1948-49 in the form of construction and in equipment at Rs. 755.0 crores and at Rs. 403.0 crores respectively. To obtain the proportion of construction and equipment of the total replacement we use the ratio of gross investment in the form of construction in 1915-16 to gross investment in the form of

equipment in 1928-29 both of which come up for replacement in 1948-49.

$$\frac{\text{Construction component of replacement in 1948-49}}{\text{Equipment component of replacement in 1948-49}} = \frac{755e^{-.015(33)}}{403e^{-.015(20)}} = \frac{1.5}{1.0}$$

Price indices for 1948-49 (1959-60 = 100) for construction and for equipmer are 86.8 and 72.1 respectively. Then the 1948-49 replacement in 1959-60 prices is

$$R(6) = (611.0)\ \frac{(1.5)(.866) + (.721)}{(2.5)} = 755.0 \text{ Rs. Crores}$$

Assuming that all depreciated capital was replaced in 1948-49 we have $D(6) = R(6) = 755.0$ Rs. Crores. Then

$$D(t) = 755e^{0.015t} \qquad t=0 \text{ in } 1948\text{-}49$$

The overall levels from this formula checked reasonably well with aggregate depreciation estimated by the Central Statistical Organisation of the Government of India for various years[1] and with other order of magnitude calculations in which we assumed steady states with different life spans and savings rates.

Replacement requirements by sectors have been estimated by Vinod Prakash for the decade of 1961-71.[2] However replacements in a number of sectors including, railways, roads and housing are not given by Prakash and have been separately estimated by us. This sectoral distribution of depreciated capital is assumed unchanged from year to year for the Third

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1 Estimates of Gross Capital Formation in India for 1948-49 to 1960-61, New Delhi, 1961.

2 "Studies in the Structure of the Indian Economy," Report No. 1, M.I.T. Center for International Studies, July 28, 1964.

and the Fourth Plan periods. The depreciated capital is shown in Table 3-17. The corresponding matrix of proportions r is given in Table 3-17. Table 3-19 shows the matrices r', r'' and r''' which are obtained from lag requirements similar to those of p', p'' and p'''.

3.4.2 Exports

For the Third Plan period exports are projected assuming constant sectoral composition from the 1960-61 levels using a single annual growth rate. These projections are given in Table 3-20

Estimates of exports are given in Notes on Perspective of Development, India for 1965-66, 1970 71 and 1975 76. Assuming a constant yearly rate of growth and the same composition of exports as that in the year 1970-71, the yearly vectors of exports are obtained for 1965 1971. These are given in Table 3-21

3 4 3 Government

The government sector in the planning models is assumed to consist entirely of "public consumption" so that resources delivered for this purpose do not contribute to productive capacity nor act as intermediate inputs to producing sectors.

For the Third Plan period government expenditures are projected by means of an assumed growth rate of 4% which is used to extrapolate the sectoral levels of government demand presented in the I S.I table. This sectoral composition is also applied to the projections of aggregate government expenditure made in the P P D., Notes in order to obtain estimates for the Fourth Plan period. These estimates are shown in Tables 3-22 and 3-23.

3.4.4 Consumption

The models require specification of the proportions in which the total consumer budget is allocated among the output of the producing sectors. The exogenous specification of the initial and subsequent consumption proportions are based on the I.S.I. table for 1960-61. These proportions are shown in Table 3-24.

3.4.5 Net Foreign Capital Inflow

For most of the solutions net annual capital inflows are set at Rs.500 crores and the consequence of changes in availability are analyzed in alternative solutions. As noted above the allotment of foreign aid on an annual basis will lead to different results than specification of a total amount to be available over the entire plan in whatever annual pattern desired.

3.4.6 Initial and Terminal Capital Stocks

The endowments of capital stocks with which the Plan period starts are initially the only productive resources available. These endowments are the results of events in the pre-Plan period and exogenous to the Plan itself. Likewise, the amounts of uncompleted capital, whose construction was started prior to the Plan period with a view to completion during the Plan, are exogenous. These endowments of completed and uncompleted capital are the means by which events in the planning period are related to events in the preceding plan period. In any actual planning procedure these initial conditions will be estimates based on whatever empirical information is available prior to the beginning of the new plan period. In applying the models, we attempt to simulate the planning

process by placing ourselves in the position of the planners and, therefore, also rely only on data for the pre-plan period in setting initial conditions. However, since we do not have detailed empirical information with which to estimate the initial capacities and capital goods in process at the outset of the Third and Fourth Plans, a somewhat arbitrary procedure is adopted to overcome this obstacle. The initial conditions are projected using the output levels in the pre-plan year, X(0), and the sectoral growth rates as shown in equations 9.0, 9.11 and 9.12 in Chapter 2, Table 2-2. As explained there these equations embody the assumption that the sectoral growth rates projected for the succeeding plan period determined the investments made in the three pre-plan years. With respect to capital-in-process it is thus assumed that enough is created in the pre-plan years to maintain the sectoral growth rates projected for the succeeding plan period.

On the other hand, it is assumed that output levels in the year just prior to the Plan, from which initial capital stocks were projected with the assumed Plan growth rate, are based on full use of existing capacity. The adjustment for less than full use of capacity in order to determine initial effective capital endowment could be a significant one since even small errors here may correspond to a substantial portion of the annual amounts of investment, and there has been repeated citation of the existence of unused capacity in the Indian economy. However, this adjustment could not be made due to lack of data on idle capacity. The well-known problems of defining capacity occur in an aggravated form in such sectors as traditional agriculture, of course. Change in effective capacity may also occur due to improvements in operating efficiency as

personnel become more skilled. Where new projects are a substantial fraction of the total capital as in the Indian steel industry, this can be quantitatively quite important. At this point in the model development it would be most convenient to introduce this as an exogenous effect but due to lack of specific information no adjustment of this sort has been attempted.

For the Third Plan period the output levels for the pre-plan year are taken from the modified input-output table for 1960-61, Table 3-3. The projected growth rates are those implied by the Third Plan targets. The Third Plan targets for the thirty sector classification of the I.S.I. input-output Table 3-2 are taken from estimates by M. R. Saluja.[1] The targets for Housing and Others and Margins were projected separately. The targets for all thirty-two sectors are shown in Table 3-25. Table 3-26 lists the output levels, X(0), and the growth rates, α_0 and α_T, which are used in the model solutions for the Third Plan period.

The pre-plan and target output levels for the Fourth Plan period are estimated from the P.P.D., Notes. In these Notes sectoral output levels are furnished only for the "organized" part of each sector. Therefore, in order to provide comprehensive sectoral data, it was necessary to estimate the output of the "unorganized" portion of the sectors. It will be seen that the character of the Fourth Plan Target Model solutions is to some extent dependent on the manner in which this is done and two alternatives are provided. In both cases it is assumed, for lack of any other basis on which to proceed, that in each industry

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1 Studies in the Structure of the Indian Economy, Report No. 5, "Methods and Sources for Output Levels, 1960-61 and 1965-66."

the ratios of the output of the organized and unorganized portions of each sector were unchanged since 1960-61, the last year for which comprehensive data were available.

The P.P.D., Notes also provide sectoral output levels for 1960-61 for the "organized" part of each sector. From these and the output levels for 1960-61 of Table 3-3, coverage adjustment ratios are obtained which are then applied to the P.P.D., Notes sectoral output levels of 1965-66 and 1970-71. This implies, of course, that output in both parts of each sector has grown at the same rate. This is a patently unsatisfactory method but no alternative procedure available to us seemed to be an improvement. Moreover, it provides some justification for continuing to use the same capital-output ratios and other technical coefficients. The computations to obtain a comprehensive coverage are first carried out on a thirty-two sector basis, the results then being aggregated to the eleven sectors in which most of the solutions are calculated. It was brought to our attention that this disaggregation may give a disproportionately large influence to the unorganized part of the fastest growing organized sectors. When the adjustment for coverage is carried out in the same manner on an eleven sector basis, this effect is reduced and, as a result, the total output levels are also reduced.

Terminal year output levels for the Fourth Plan Target Model calculations are also estimated from the P.P.D., Notes 1970-71 output levels with the adjustments for coverage made as described above. Once again adjustments are made on thirty-two sector basis as well as on eleven sector basis and two sets of output levels are obtained. With these pre-plan and final year output levels for each sector, growth rates

are calculated which are then used to project the capital stocks and the capital-in-process at the beginning of the Fourth Plan period on the same assumptions used previously. Table 3-26 shows the two sets of initial and terminal outputs and the intra-plan growth rates.

To complete the specification of post-terminal conditions for the Target Models the sectoral growth rates must be determined for the three post-plan periods. Lacking information on this subject for the Third Plan period we simply projected the previously derived intra-plan growth rates. On the other hand, the P.P.D., Notes specify growth rates for the Fifth Plan period which, however, are lower in all sectors than the projected Fourth Plan growth rates. Again, solutions were calculated for two versions: with the intra-Fourth Plan growth rates projected for the post-terminal period and with the Fifth Plan growth rates of the P.P.D., Notes. The latter not only imply a sharp discontinuity in growth rates at the end of the Plan but also a lower growth rate for Fifth Plan as compared to the Fourth Plan. Consequently, for most runs we have used the Fourth Plan growth rates.

3.5 Some Notes on the Quality of Data

The data presented above have been collected and prepared primarily for the methodological purpose of developing a set of techniques to assist in making economic policy. We shall attempt to draw some practical insights from the model solutions and expect that others will evaluate them in the same way since we claim that the data are "realistic" in the sense that they are within the realm of observed experience for some country, if not always for India itself. On the other hand, the data may or may not be "real" in the sense of exactly representing India, for even with much

more knowledge than we have, such a claim would be intrinsically difficult to maintain.

The data used might tentatively be grouped into three categories: (i) technical parameters and quantities, (ii) behavioral parameters and (iii) policy parameters and quantities. The intermediate flow coefficients, capital-output and inventory coefficients would appear to fall into the first category which would also include estimates of initial productive capacities. Consumption proportions are examples of the second category, while policy quantities and parameters would include plan targets and post-terminal consumption growth rates, net foreign capital inflows and, to some extent, import coefficients. Import coefficients, however, are to some extent, technically determined but not uniquely so as they respond to market forces and direct government controls. Moreover, what is true of import coefficients is, in fact, true of nearly all the "technical" data. The so-called technical input-output coefficients are not determined by technical factors alone but by market influences and government policies working outside the market, as for example, those policies which determine the size of new plants in a particular sector by means of investment licensing procedures. While the range of potential variation of some technical coefficients, as in electricity generation, may, in fact, be narrow, in other sectors such as transportation or food and clothing production the potential variation can be substantial. Yet even where variations are possible important changes may not be easily achieved but may come only with considerable cost and effort which draw attention and emphasis from other activities.

These considerations as well as the more obvious limitations of our sources contribute to the uncertainty as to whether we have been able to establish the "true values" of the data. Some of the uncertainty is associated with our essential ignorance of the future; some with the difficulties in judging the will, determination and ability of policy-makers and some is due to ignorance of current or past values of parameters which are either used directly or which form the basis for prediction. Thus, some but by no means all of the uncertainty could be dispelled by closer contact with data sources and improved data gathering, collection and processing.

One of the features of the models is that they require explicit attention to many empirical issues which are not raised by other planning methods and in this sense their demands for data are greater than those of less detailed planning procedures. We regard this as a virtue rather than a weakness since in India there are actually, or potentially, reasonably satisfactory means of satisfying most of the data requirements. Yet because of these enlarged data requirements we have not been able to rely on a single Indian source in developing the necessary information nor even, in most cases, to use a set of information from a single source without augmenting or modifying it. A brief review will emphasize this aspect of the data preparation and assist in a summary judgment as to the strengths and weaknesses of the empirical procedures.

The a, b and p matrices were for the most part based on recent Indian estimates. The a matrix was modified to isolate a Housing sector and aggregated. The b and p matrices were augmented

to provide information for these additional sectors and agriculture using data from India and other countries as a basis. Thus these coefficients can only be considered as representative of a current range of values. In agriculture, for example, while a capital-output ratio of 1.5 has been used in most trials the currently effective ratio may range from a value not much less than 1.0 to, perhaps, somewhat over 2.0.

The aggregate values of the s coefficients were, for the most part, estimated from Indian sources but the Indian estimates were reduced drastically to make them more comparable with data for other countries. Again they represent a range and are likely to be at the low end of the range with some possible exceptions where alternatives are investigated explicitly. The distribution of the aggregate s coefficients was based on the input-output table. This procedure is plausible but not founded on empirical study.

Likewise the lag proportion matrices are based on a plausible assumption and some quite generalized knowledge but no specific study and again the consequences of alternative assumptions are investigated.

The import coefficients were based on the I.S.G. matrix mentioned earlier but modified on the basis of rough judgments as to the degree to which additional imports would be accepted in particular sectors.

Depreciation was projected by means of rough calculations using macro data for India.

Exports and government consumption were simply extrapolations of past levels and growth rates.

Consumption proportions were based on the modified I.S.I. table.

The pre-plan output levels were taken from Indian data but to obtain initial capital stocks it was necessary to assume full use of capacity and some sectoral growth rates. These were backward extrapolations of proposed plan growth rates. These were also used to project initial capital in process. For the Fourth Plan period both initial and target year output levels had to be computed from incomplete data and were, therefore, adjusted for coverage. The adjustment procedure is uniform for all sectors and a rough approximation at best.

There are many places in which judgment was necessary as to current and future plausibility of the numbers. In general we attempted to make these judgments in the direction which would favor Indian economic growth opportunities as revealed by the solutions without being implausibly optimistic. Obviously this background of the data suggests great need for caution in interpreting results which we shall try to observe and which we recommend to the reader.

CHAPTER 4

TARGET AND TRANSIT MODEL SOLUTIONS

FOR THIRD AND FOURTH PLAN PERIODS

There is no toy
Called easy joy
But man must strain
To body's pain
Even Vishnu embraces his bride
With arms that had to churn the Milky Way.

--The Panchtantra

The preoccupation of policy-makers with short-term plans was the inspiration of the first models described in Chapter 2.

There are good reasons for the conventional concentration of attention in less developed areas on short-term economic plans of, say, four to eight years. The time span is long enough to complete most types of major industrial, agricultural and utility projects and also to begin to judge the results of schemes which do not involve long time lags. Fluctuations in agricultural output due to natural causes can normally be expected to have averaged out over four to eight years. The political future is often reasonably clear as terms of office often have more or less the same length. It is desirable to have a re-examination of premises and appraisal of results at intervals which are long enough to permit an evaluation but not so long to permit a compounding of errors. Altogether there is much to be said for using a period for detailed economic policy that is longer than two or three years but shorter than ten years.

However, there are also dangers in short-term planning. A preoccupation may arise with the present and near future which is so intense that the essential dependence of short-term plans on long-term plans is ignored and the interrelationships between plans are neglected. In general it is true that myopia does not lead to economic efficiency. It is also not true that economic policies can be made only <u>seriatim</u> within the order imposed by the progression of time. Short-term plans and policies must be given a context and direction by long-term plans.

These propositions are the result of the essential interrelationships between the past, present and future in the minds of men and in the technical relations of production and the creation of productive capacity. Long-term policies must not be considered inviolate over their lifetime. Unexpected events of various types: shortfalls, over-achievements, new technologies, changing markets, changing birth and death rates, all require continuing readjustments of long-term goals and the short-term policies which implement them.

In this chapter the Target Model is applied to the examination of the Indian Third and Fourth Five Year Plan periods. Solutions are calculated embodying the Plan Targets for a number of specifications of parameters and constraints. The purpose is to explore the effects of different policies and the sensitivity of the results to alternative estimates of production conditions, export prospects and foreign economic assistance. In illustrating the use of the Target Model to judge the consistency and feasibility of the Plans, criteria and constraints are applied which we believe to be reasonable representations of reality. However, the caveat must be registered again that these are not necessarily the criteria and constraints implicit in the Plans themselves.

4.1 Target Model Solutions for the Third Plan

Though the overall growth rate of output implied in the Third Five Year Plan was about five per cent, the growth rates for specific sectors varied substantially from this figure. Table 3-25 indicates the 1960-61 gross output levels, the projected 1965-66 levels and the implied average annual growth rates for the thirty-sector detail of the ISI input output table and for the eleven-sector detail in which all the solutions are

calculated. When initial output levels are quite low, as for example in the case of fertilizers, growth rates can be misleading indicators of the relative emphasis of the Plan. Yet the overall impression is relatively straightforward. With the exception of fertilizers the highest growth rates are in the capital producing sectors, in their most important suppliers and in several major import substituting sectors. The sectors supplying consumer goods, which in India include relatively small amounts of consumer durables, on the whole had lower growth rates projected for them. The rationalization of this relative emphasis has been based on several related arguments. Capital is necessary to provide the means with which to increase output in the consumer goods sectors and the well-known accelerator effect accounts for the more rapid growth of the capital goods producing sectors themselves. It is claimed that the improvement in the individual standard of living would be greater and most satisfying over a longer planning period by postponing the period of most rapid growth in consumption. With given export prospects the need for foreign exchange, and therefore, for import substitution is implicit in the decision as to the rate of investment. Capital is necessary to create import substituting industries in order to reduce the country's reliance on foreign aid.

A five year model can provide only a limited test of a long run rationale. Such a test may nonetheless be decisive. Are the Five Year Plan Targets feasible? If so, the model will help indicate an "optimum" way of achieving them. If this test is not met, a long run analysis of the Targets is beside the point for there is no way of transferring resources from the future to the present.

Feasibility of a set of targets cannot, however, be finally decided by a formal test using the Target or any other model. It remains essentially a matter of judgment to which calculations with a model can contribute. For example, attempts to find solutions to the Target Model with a specific set of targets might indicate "technical infeasibility," i.e., that with the given set of relations, constraints and parameters there is no way of achieving the targets. Even such a result is not decisive. In the real world constraints and parameters depend in part upon policies pursued and can be altered by 'greater organizational efforts' or 'more intense mobilization of resources.' In this sense the Target Model can only provide a test of consistency of the various specifications, and "technical infeasibility" simply means inconsistency. On the other hand, the finding of a solution to the Target Model is no guarantee that the plan targets are practically or "operationally feasible" and socially acceptable. The formal structure of the Target Model omits many economic and political conditions which in reality may be quite important and, in a complete evaluation of any solution these omitted conditions must be made explicit. For example, the question must be raised and resolved as to whether governmental and private market organizations can and will implement the plan. As one test of operational feasibility we shall compare the savings and investment plans with the requirements as estimated by the Target Model solutions. This test is both economically important and relatively straightforward. There are other tests, such as availability of managerial skills, which may be equally important but, partly because they cannot be so easily quantified, they are more subtle and difficult to judge and will not be dealt with here.

In order to present the results in an expeditious manner much of the discussion will be conducted in terms of a Reference Solution. To explore alternatives the parameters of the Reference Solution are usually varied one at a time. The Reference Solution is not to be interpreted as our best guess as to the solution most applicable to the Third Plan targets. It serves only as a standard against which to judge the results of changes in constraints and parameters and as a means for explaining the operation of the model. In the following full details of the solutions are presented only for the Reference Solution. For the variations, only the highlights are described.

4.1.1 Assumptions for the Target Model Reference Solution of the Third Plan

The assumptions for the Reference Solution as to parameters and exogenous requirements are as follows:

(1) The technical coefficient matrices a, b, s, p', p'', p''', r', r'' and r''' are assumed constant throughout the plan period and are the reference values presented in Chapter 3.

(2) The consumption coefficients, c(t), non-competitive import coefeficients, m', and competitive import ceilings, m'', are also assumed constant throughout the plan period.

(3) Requirements of $\overline{E}$, $\overline{G}$ and $\overline{D}$ are exogenously specified at the levels shown in tables of Chapter 3.

(4) Net foreign capital inflow is fixed at a constant value of Rs. 500.0 crores per year.

(5) The discount rate w for consumption is fixed at 0.10, i.e., 10.0 per cent.

(6) The minimum growth rate of consumption $\rho(t)$ is set at .025, i.e., 2.5 per cent for all the periods which is roughly equal to the population growth rate. However, $\overline{C(0)}$ in restraints (2.01) of Table 2-3 is set at zero. This permits the optimisation procedure to reduce C(1), the level of consumption in the first period, as necessary to meet the consumption growth constraint of later years. Thus it becomes possible to find a solution with levels of aggregate consumption so low as to be obviously unacceptable whereas if the constraint were maintained only a showing of technical infeasibility would result. This is an example of a case in which the feasibility issue is not a matter for the model itself to decide on the basis of the conditions which are part of its structure but also requires a political evaluation of the result.[1]

(7) The initial outputs $\overline{X(0)}$, the terminal year output targets $\overline{X(5)}$ and the implied growth rates are those from Table 3-26.

With the parameters and constraints as specified no feasible solution could be found which was consistent with the Third Plan Targets. That is, even with a maximand reduced to zero, i.e. with absolutely no diversion of resources to producing consumption, there was no set of allocations of available resources which could create enough capital to reach the target levels of output. This failure to find a solution for the Third Plan Targets provides a useful contrast between the real world and the manner in which the model works. In reality if Plan targets are technically infeasible, the economic system will not "break down" and produce nothing, but will violate a constraint, for example, by

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1 A solution even if politically unacceptable yields much more information about the structure of the system than the finding of infeasibility so it is desirable to avoid that if possible.

underachieving the Targets. In a solution to the model, however, the constraints must be met and, if they cannot be, there is simply no solution at all.

Without a solution there are, of course, no shadow prices to indicate the relative significance of the various constraints. Experiments with changes in inventory coefficients, capital coefficients and lag structures finally led to a feasible optimum solution for the Third Plan Targets when all these were reduced to what we consider optimistic values. However, this solution is unsatisfactory for studying the sensitivity of the solutions to parametric changes as most variations which we want to study would give an infeasible solution. The solution which will be used as a Reference Solution is obtained by reducing the Targets to the 96% level in all the sectors. The various alternative runs with different parameters are made with respect to this Reference Solution with 96% level of targets. The particular changes in parameters are described when the results of the various runs are presented in Section 4.1.3.

In solutions with 96% level of targets the growth rates α_o for estimating initial capacity and initial capital in process are still those from Table 3-26 and correspond to the 100% level of targets. However, for projecting post-terminal capital requirements, the growth rates used in these solutions always correspond to X(0) and the particular level of targets X(5) in the solution.

4.1.2 The Reference Solution for the Third Plan

A complete description of the Reference Solution is given in Tables 4-1 through 4-50.[1] These indicate the kind of detailed information that is obtained and will be used to describe the detailed operation of the model. The comments on this solution in this section are intended only to underscore some of the more interesting points. Evaluation of the implications of the Third Plan targets cannot be made until all the parametric variations are also described.

The linear programming solution itself evaluates only the unknowns of the model, gross domestic outputs, X(t), for t = 1 to 5; competitive imports M"(t), t = 1 to 5; available capital stocks K(t), t = 2 to 5; restored capacity R(t), t = 2 to 8; new capital Z(t), t = 1 to 8; and aggregate private consummation C(t), t = 1 to 5; and the shadow prices. The remaining details in Tables 4-1 through 4-65 are implicit in the solution and are generated from the optimal solution.

The sectoral levels and the growth rates of outputs in each year are shown in Table 4-1. As would be expected from the targets, the fastest growing sectors are nearly always the capital goods sectors and their major suppliers. Agriculture and Food and Clothing and Housing, the major consumer goods producing sectors, are among the slowest growing. In no sector do the outputs in different years grow either linearly or exponentially, and the growth rates fluctuate from year to year. However, this is to be expected since the composition of targets is different from the composition of initial capacities. The growth rates in the fifth year are not "actual" growth rates but relate only to the full capacity output

1 The tables for this chapter are presented separately in the accompanying volume.

levels, which may be internally inconsistent, for the sixth year. The growth rates for the sixth and seventh years are the post-terminal growth rates α_T implied by $x(\overline{5})$ and $x(0)$. Since the output of Housing is used only for private consumption, it grows at the same rate as aggregate private consumption. The sudden increase in the growth rate in Others and Margin between the fifth and the sixth years is due to the fact that we set the target output in this sector at the 1960-61 proportion of the sum of the gross domestic outputs targets in the remaining sectors. Since Others and Margin, is primarily a consumption sector, the same proportion in 1966-67 as in 1960-61 may be inappropriate as the proportion of investment goods and consumer goods in the economy change over the years.

The shadow prices of outputs which indicate the value to the maximand of an additional unit of output are shown in Table 4-2. These are the shadow prices associated with the distribution relations. The shadow prices of output help indicate the priorities in resource allocations which are taking place. The highest shadow prices and, therefore, the greatest stringencies are, for the most part, in the capital forming sectors, Construction and Equipment and in their major supplying sector, Mining and Metals, and Cement and Non-Metals. The shadow prices in the major consumer goods producing sectors, Agriculture and Plantations, and Food and Clothing, are relatively low. This occurs, even though the optimization mechanism is trying its best to produce consumption goods, because the model's primary obligation is to meet the targets and to satisfy the various other constraints. Thus the low shadow prices of consumption goods are an indication of the strains that the targets and other constraints are putting on the system. The strikingly high shadow price of Cement and Non-Metals in the third year is explained later.

The sectoral levels of private consumption in each year are shown in Table 4-3. These levels are calculated from the fixed consumption coefficients and the aggregate private consumption in each period as determined by the solution. The level of private consumption in the first year is Rs. 13050 crores which compared with the actual level of Rs. 12605 crores in the pre-plan year 1960-61 is a growth of 3.5%. From the third to the fourth year private consumption grows by 6.1% and from fourth to the fifth year by 4.0%.

The consumption growth constraints have non-zero shadow prices in the second and the third year. These indicate that, were it not for the consumption growth constraints, the solution would have provided more consumption in the first and the second years than what was actually done. It did not do so because it could not then have provided the required additional consumption in the third year. This might be interpreted as a tendency to concentrate consumption in the first year. On the other hand the fact that consumption growth constraints are not binding in the fourth and the fifth year indicates that the solution does not have a tendency to concentrate all the consumption at the beginning of the plan. This apparently contradictory behavior in the first two years is due to the initial capital in process specifications which restrict the capital stocks available in period three to such levels that they cannot generate more consumption along with the investments necessary to meet the prescribed targets.

Tables 4-4, 4-5, 4-6 and 4-7 which reveal the availability and intensity of use of capital stock provide a great deal of insight into the solution. From Table 4-4 it is seen that maximum increment in capital

stock occurs in the sixth year. With an unconstrained flip-flop behavior of the solution, in which consumption is concentrated in the last year, the solution would hold down consumption in the early plan years in order to provide as much capital as possible by the fifth year. It would then use this capital to produce private consumption in the fifth year. This doesn't happen here because the three-year lags in investments require that investments must be started by the second year to mature in the fifth year and the maximum capital stocks in the first two years are externally specified.

In Table 4-6 the excess of actual capacity over the targeted capacity in Construction in the sixth year indicates that even more capacity in Construction is required in the fifth year than targeted to meet the investment requirements in the fifth year. The capital stocks in Agriculture and Transport sectors have reached the target levels by the fifth year. Both these capacities are fully required to meet the demand for Agriculture and Transport in the fifth year and there are no idle capacities in the fifth year. Since capital stocks increase in the sixth year in other consumption goods sectors, this increase would imply that the consumption proportions would not be maintained in the sixth year if aggregate private consumption is to grow and if imports in agriculture sector are not increased. If the level of investment is also maintained, a transportation shortage would also develop as private consumption is increased.

The idle capacities listed in Table 4-6 in the first years are mainly in the consumption goods sectors. On the other hand, capacities in capital producing sectors Construction and Equipment and their major

supplier Mining and Metals and Cement and Non-Metals are fully utilized in the first year. The distribution of the excess capacity reflects the lack of "balance" between the composition of the capital stocks existing at the outset of the Plan and the composition of the Targets. The capital stocks at the outset of the Plan, estimated from pre-Plan output levels, are geared primarily to the production of consumer goods. Capital in the Mining and Metals, Equipment and Construction sectors account for only 8.8% of the total endowment. By the end of the Plan period these sectors were intended to account for over 14% of the total capacity.[1] This change in composition requires that roughly 32% of the total investment over the Plan period go to these three sectors in the Reference Solution.

The idle capital in all the sectors in the second year as shown in Table 4-6 is striking since it appears to be wasteful. The reason why this capacity could not be used in producing more consumption is because the consumption growth constraint would in turn require a higher level of consumption in the third year. As explained above more consumption in the third year could not be provided while at the same time producing the investment required to realize the targets. The third year bottleneck cannot be broken because the maximum capital stocks in that year are specified by initial conditions. On the other hand, the excess capacity in the second year could not be used in the creation of capital goods for investment either. The lag structure of investment is rigid and requires that investment in each sector be made in three successive years. Since the

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1 Since the plan targets were scaled down uniformly by 4%, the reduction in the level does not affect this comparison.

solution has no excess capacity in Construction in the third year, if additional investment were made in the second year it could not be complemented with the further investment which would be necessary in the third year to complete it. However, from Table 4-9 it is seen that the solution did not complete the initial unfinished investment in Construction in the third year and it appears as if more construction capacity could have been provided in the third year. This would have then made it possible to complement additional investment in the third year and eliminate excess capacity in the second year. Yet it can be seen from the "a" matrix that the production of Construction needs Cement and Non-Metals as current input. But additional output of Cement and Non-Metals could not be provided since there is no excess capital in Cement and Non-Metals sector. This also explains why the shadow price of Cement and Non-Metals is so high in the third year. An additional unit of Cement and Non-Metals would make it possible to use some of the excess capacity in the second year. Still this is not quite a complete explanation. Why not divert in the third year one unit of Cement and Non-Metals from consumption to the use as an input to the Construction sector? If this were done fixed consumption coefficients would require that about 200 units of aggregate consumption would have to be sacrificed before one unit of Cement and Non-Metals would become available. However, because of the additional consumption generated in later years the cost of this sacrifice is just 117.04 units, the shadow price of Cement and Non-Metals in the third year.

The above tale with its plot and sub-plots demonstrates the interplay of many assumptions and forces within the model. It underlines for example the effects of the assumption of three year lags in rigid sequence

and shows how the whole solution is affected by this assumption. This assumption in turn would not be so critical as is shown below, had there been lower targets or higher initial capacities.

The shadow prices in Table 4-8 are the rental price of capital in each year. The rental price is zero whenever there is idle capacity in the sector. Thus the rental price of capital can be zero even when the output produced with it has a non-zero shadow price. The new capital capacities that mature at the beginning of each year are shown in Table 4-11. New capital is being created in most of the sectors in each period. Among the capital goods sectors, Construction, Equipment, and their major supplies, Cement and Non-Metals and Mining and Metals sector, only Mining and Metals has a large increment in capacity in the sixth year. Unless an increase in the demand for Mining and Metals is envisioned either due to changes in production or consumption coefficients or due to increase in exports or decrease in imports, excess capacity would result in this sector in the sixth year. However, it should be noted that in the Reference Solutions no provision is made for any import substitution program and that Mining and Metals sector may be especially important in such a program.

A large increase in capital stock in Electricity occurs between the fifth and sixth year when the available capital stock doubles. The solution doesn't create this capacity earlier since there is no need for it in the intra-plan period and the capital-output ratio in electricity is quite high. The high level of target output in Electricity may reflect programs of rural electrification not reflected in consumption proportions or new industrial demands not prescribed in the technical coefficients in

the model. If increases in electricity demand due to such changes are not foreseen, Electricity would show excess capacity in the sixth year. In the Others and Margin and the Electricity sectors, excess capacities exist in the first four years and yet new capital is created in the second and the third years. This is because the initial capital in process created before the plan started must be completed in the second and the third year or else it would be lost. The solution prefers this cheaper means of creating capital capacity than to abandon this part of the initial endowment and begin completely new capital later. This also explains why capital in Housing is created in the second and third years even though there is excess capacity in Housing in these years.

The impossibility in the model of interrupting the sequence of investment also results in initial capital in process being lost in a number of sectors because it could not be completed due to the shortage of Cement and other Non-Metals. This is seen in Table 4-9 where many sectors have ratios less than one for the third year. In a real application this might be taken as indicating the areas in which efforts must be made to relax one or more of the constraints which lead to this result. For example if it were possible to interrupt the sequence of investment in a planned way by starting new investment and then delaying it when particular resource requirements were scarce, the overall performance of the system would be improved.

The shadow prices of new capital in Table 4-12 correspond to the capital accounting relations (5) of Table 2-3. For the first four years, the difference between the shadow price of capital in two successive years is the rental price of capital in that year. If the rental value

is zero, as it is when it is not used, the shadow prices of that capital remain constant. In the sixth year, i.e. at the end of the fifth year, the shadow price of capital reflects not the future usefulness or productivity of this capital but the cost in terms of private consumption over the five plan years which had to be foregone in order to create the amount of capital that the targets stipulated. This is because the post terminal stream of private consumption is not included in the objective function explicitly but only through the stipulated requirements of terminal capital stocks. The effect of providing for post-terminal consumption through minimum terminal capital stocks constraints which must be satisfied is similar to having an objective function with weights of infinity on terminal capacities for values below the targeted levels but with weights of zero once the target level is reached. Consequently, when the stipulated terminal stocks are provided further additions to these stocks which would increase the post-terminal stream of private consumption have a zero value to the objective of the solution. This also explains why the shadow price of capital falls with time.

Tables 4-13 and 4-14 show the restored capacities and the ratios of restored capacity to depreciated capacity. A ratio other than 1.0 indicates decumulation of capital. However, the zeros in Transportation and Housing sectors are misleading since these two sectors require only Construction as capital (since for Transport the special assumption is made that no new construction is required for the Third Plan period). Consequently the costs of restoring are the same as those for creating new capital. This makes the solution indifferent as to restoring or creating new capacity in these sectors. Capital decumulation, however, does take place in the 'Others and Margin' sector in the fourth and fifth

years, in Chemicals and 'Food-Clothing-Leather' sectors in the third year and in Electricity in the fourth year. For the eighth year zeroes do not indicate decumulation since only construction has a three year lag, and so only the construction part of the eighth year's new capital is invested during the plan period and once again the solution is indifferent as to restoring or creating capacity in these sectors. The shadow prices in Table 4-15 are the values of the undepreciated capital components of restorable capacities. For Construction and Transport sectors where there is no undepreciated component left, the non-zero price corresponds to the price of new capital.

In addition to capital, production in most sectors requires imports. Total imports in each sector are listed in Table 4-16 and the allocation between non-competitive and competitive imports is shown in Tables 4-17 and 4-18. The so-called "non-competitive" imports it will be recalled are tied to the level of output in the sectors in which they exist. The total amount of imports is limited to the sum of the exports and net capital inflow, including economic assistance. The "non-competitive" imports are nearly 50% of the total in the first year but rise to 85% in the fifth year as output increases.

The non-competitive import coefficients are assumed constant throughout the plan period. The neglect of import substitution programs could hold down the levels of domestic production below what is otherwise feasible. This however, has not happened as is shown by the existence of some competitive imports in all the five years. Since the non-competitive import coefficients establish floors on imports and since competitive import ceilings operate only on the "left-over" foreign exchange the distribution of imports is affected by both the non-competitive import coefficients and the competitive import ceilings.

Interpretation of the pattern of imports is facilitated by the use of the shadow prices on the competitive import ceilings and the prices on the foreign exchange balance constraints which are shown in Table 4-19. These latter shadow prices are higher in the later than in the earlier periods in spite of the greater stringency of resources in the first periods.[1] This is because the competitive import ceilings force the allocation of foreign exchange to sectors which in early years have lower shadow prices. Furthermore, as explained in Chapter 2, the shadow price on the foreign exchange balance constraint is the value of the least valuable output among the sectors to which non-competitive imports are made.

In each period the model allocates the available foreign exchange which is not used for competitive imports first to the sector which can import and which has the highest shadow price on its output. Imports continue in this sector in this period until the sector's competitive import ceiling is reached. The allocation of foreign exchange then switches to the sector in which it is next most valuable in the same period, and again proceeds until the sector's import ceiling is reached. In all periods Agriculture has the lowest priority for the use of foreign exchange for competitive imports as is seen from the fact that price on the Agriculture import ceilings is zero in all years. Agriculture thus receives whatever is left over after the ceilings have been reached in other sectors. In this solution it is, therefore, always Agriculture whose shadow price is equal to the foreign exchange balance shadow price.

The highest price on competitive import ceilings in the first year is on Equipment whereas the output of Cement and Non-Metals has the highest

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1 Imports of the outputs of the Electricity, Transportation, Construction and Housing sectors are not allowed and there are no non-competitive imports in the Other and Margin sector.

shadow price in the first year. This is because the price on competitive import ceiling does not reflect the value of an additional unit of competitive import in that sector but the value of an additional unit on the right hand side of the particular constraint. The shadow price for the competitive imports in Cement and Non-Metals should be 117.00336, which is the shadow price of Cement and Non-Metals, 117.04334, minus the shadow price of foreign exchange in the third year, 0.03998. The competitive import coefficient for Cement and Non-Metals is .02 and so 50 units of foreign exchange on the right hand side of its competitive import ceiling are required to have one unit of Cement and Non-Metals. From Table 4-19 the price for the constraint on Cement and Non-Metals is 2.34007 and the value of the 50 units become 50 x 2.34007 = 117.0035 which is the same as the value of an additional unit of competitive imports in Cement and Non-Metals above.

Tables 4-20 through 4-49 provide detailed information for the solution on the sectoral patterns of output and the use of resources in each period: the intermediate flows, production and replacement of fixed capital for various maturities, production for inventory and the holdings of inventories, imports, exports and government consumption. These tables amplify the previous exposition and demonstrate the specific workings of the system. The summaries of the sources and the uses of output in each period are particularly enlightening.

Finally the national income accounts for each of the five years are summarized in Table 4-50. Since government expenditure in the solution represents only the consumption by government, value added by the government must be added in calculating the national income. This component is assumed to be a fixed proportion of the government consumption. Total

investment includes inventory change, fixed investment and replacement. To the extent that restoration is not distinguished from new capacity creation by the solution, replacements are understated and fixed investments are overstated. The net national product is also overstated by the same amount.

The total investment requirements for the plan period add up to Rs. 18218.72 crores for the 96% level of Third Plan targets. This corresponds to a net investment requirement of about Rs. 13700 crores of which Rs. 2322.0 crores are for inventories and Rs. 11,400 crores for fixed investment. This estimate of total investment depends on the capital coefficients, inventory coefficients, initial and terminal capital and capital in process. It would change if any of these changes. It is not dependent on the assumptions of any particular lag structure, or of any particular composition of private consumption, or on the assumption of the fixed composition of consumption. The estimate of investment requirements for the Third Plan targets in the official documents on a net basis is Rs. 10400 crores of which Rs. 9600 crores were for fixed and Rs. 800 crores were for inventory investment.

The domestic savings ratios in Table 4-50 are gross investment over gross national product and are average rates. Even though the savings rates would be considered high by Indian standards especially in the latter years the solution has provided increases in per capita private consumption in the first, fourth and the fifth years and maintained the per capita consumption levels in the second and the third years. The savings and investment requirements of the targets have been the focus of considerable discussion. We shall return to this issue again below.

4.1.3 Alternative Solutions for Third Plan

A single solution, while it may provide many insights, is not a complete planning exercise or test of a plan. Evaluation requires exploration not only of sensitivity to changes in technical coefficients and behavioral assumptions, but also of the effects of alternative constraints. As pointed out previously, not all of the social and economic policy objectives of a plan can be embodied in one solution or even in one model. Operation of the model requires, however, that the social welfare objectives which are considered as well as the technical and behavioral parameters be specified explicitly. Some of the alternative solutions will explore the significance of changes in these parameters. All the parameters are always subject to errors of estimation and this is also true of the initial conditions. In addition some of these quantities are subject to policy influences, and are therefore, to some extent, a matter of choice. So the sensitivity tests will include investigation of changes in the international aid and trade conditions of the system as well. The alternative solutions also help in interpretation of the behavior of the model.

Table 4-51 shows some of the major magnitudes obtained from the Third Plan Target solutions which were carried out with alternative constraints and parameters. The first attempt at a solution with the full Third Plan Targets was infeasible as reported. In calculations T-2, T-3 and T-4, the set of "lower" capital output ratios and "lower" inventory coefficients as shown in the alternate tables of Chapter 3 were tried yet no feasible solution with the full Third Plan targets could be found. Infeasibility of solution with 100% of the Third Plan targets means that there is simply not enough capacity to create the additional capital

required even if the composite consumption is reduced to zero. With three year investment lags the maximum capacities in all the sectors are prescribed for the first three years by the initial conditions. Moreover, investments must be started at the latest by the third year to meet the target capacity levels at the beginning of the sixth year. Thus, given the targets and three year gestation lags and other constraints, feasibility is solely determined by the initial conditions of capacity and capital in process. Though our own estimates of initial conditions are conjectural, in principle they are determined by prior events. Investment lags on the other hand are not immutable but may be made the object of special efforts to increase the efficiency of implementation. A solution with shorter investment gestation lags helps in evaluating the significance of such an improvement.

In solution T-5 the set of shorter investment gestation lags shown in Table 3-14 are used along with lower capital and inventory coefficients. In this case a solution was obtained with undiscounted consumption of Rs. 71832 crores. The performance of solution T-5 is striking when compared with the infeasibility of the prior solutions. In this case the most important changes in the lag structure as between Tables 3-12 and 3-14 are in the reduction of the gestation period for Construction from three years to one year and in reducing the three year lag in Cement and Non-Metals to two years. In these sectors as a result there is a wider range of capacities which can be achieved by the end of the Plan period. Furthermore, in the sectors with a two year gestation lag, new investments may be started as late as the third year in order for them to mature in time for production in the fifth year. Not only can bottlenecks be broken more quickly but also substantial additional consumption can be created. The

high shadow price of Cement and Non-Metals that was observed in the Reference Solution is eliminated in this solution and the consumption growth constraints in the second and third years are no longer binding.

The total gross investment required for solution T-5 with 100% of targets is Rs. 19171 crores which is higher than the Rs. 18219 crores required in the Reference Solution. Still, the private consumption in solution T-5 is higher in every year than the private consumption in the Reference Solution. The additional freedom provided by the shorter gestation lags is effective in eliminating the bottlenecks earlier than in the Reference Solution. Idle capacities are reduced to less than 3 per cent of the total capacities in the first three years and below 1 per cent in the last two years.

This striking performance of solution T-5 emphasizes the importance of investment lags in the growth process. Growth is a problem in economics Many of the problems in economic growth arise because of investment lags.

If there were no investment lags, fixed capital could be constructed and used in the same period in amounts limited only by availability of other non-producible resources. Associated with each particular set of investment gestation lags and a set of initial capacities is a feasible space of target stocks that can be achieved at the end of t years. Investment gestation lags become crucial only when the stipulated target stocks are close to this feasible surface. The question of technical feasibility of a set of plan targets is precisely this: are the targets within this particular feasible region or not?

Solution T-6 with 96% of Third Plan Targets is the Reference Solution and has been already described. Solutions T-7 and T-8 with social

discount rates of zero per cent and twenty per cent respectively indicate the insensitivity of the model solutions to social discount rates over this range. There are two sets of influences contributing to this result. First, it is to be expected in a linear model which would flip the concentration of consumption from one end of the time span to the other only at the critical discount rate, which was beyond 20%. Since the optimal program is the same for discount rates of 0.0% and 10.0% and differs by only one activity from the optimal program for discount rate 20.0%, this indicates that the critical discount rate is greater than 20% for the Third Plan economy as described by the model parameters. Secondly, the time period is so short and the solution so constrained by initial and terminal conditions that there is little scope for the discount rate to have an effect.

In Target Solutions T-9 and T-10 the constraints on the rate of growth of private consumption are varied. The relaxation of the minimum rate of growth from 2.5% to 0.0% in Solution T-9 absorbs some of the idle capital in the second year that is present in all sectors in the Reference Solution. This happens since it is now possible to provide some additional consumption in the first and the second year without having to provide even more of it in the third year. However, the consumption growth constraint is still binding between the second and the third year but is no longer binding between the first and the second year.

An annual growth rate of 5% in aggregate consumption provides roughly a 2.5% annual increase in per capita consumption. Imposing this requirement in Solution T-10 reduces the value of the maximand since the solution can meet the constraint only by lowering the initial level of

consumption. The growth constraint now becomes binding for the last four years.[1] Private consumption is lower in the first, second and fourth years than in the Reference Solution but higher in the third and the fifth years. The lower consumption in the second year releases Cement and Non-Metals which are used as inputs to Construction. Investment increases in the second year and idle capacity in Cement and Non-Metals is eliminated at the same time total idle capacity in the second year is increased.

In Target Solutions T-11, T-12, T-13 and T-14, the initial capacities and therefore the total capacities available to the system are adjusted directly to test the effects of possible errors in the measurement of the initial capital endowments. There have been suggestions that substantial excess capacity has existed in Indian industry and in some sectors as, for example, in the Construction industry capacity is difficult to define and measure. Changes in initial capacities help in interpreting the shadow prices. These prices on capital and initial endowments indicate the effects on the maximand of marginal changes in the effective capital available to the economy. Their usefulness as indicators of the effects of substantial changes is tested in this next set of solutions. The Reference Target Solution indicated that Cement and Non-Metals was the primary bottleneck in the early periods. In Target Solution T-11 the initial capacity in the Cement and Non-Metals is increased by 5%. This 5% increase leads to an increase in fixed capital in Cement and Non-Metals of about Rs. 22.0 crores. An additional unit of capital in the first

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1 Since $\overline{C(0)} = 0$, the constraint is inoperative in the first year.

period is worth the shadow rental price in the first period plus the shadow price of new capital in the second period. Using these shadow prices in the Reference Solution this additional capital is worth 22.0 x (24.9 + 135.2) = 3522.2 Rs. crores to the maximand. In fact, however, the actual increase in the maximand in Solution T-11 is 58550 - 57828 = 722 Rs. crores. This demonstrates the limitations in this model on using shadow prices to predict the effects of substantial changes.

The additional initial capacity in Solution T-11 eliminates the Cement and Non-Metals bottleneck; no longer is there idle capacity in the second year in Agriculture or in Cement and Non-Metals. The shadow rental price of capital in Cements and Non-Metals in the third year falls to 0.50 from 128.38 in the Reference Solution. Now, however, the solution runs into Construction capacity limitations and the rental price of Construction capital rises from 4.14 to a maximum of 144.17 also in the third period.

In the Reference Solution it seemed that if only the shortage of Cement and Non-Metals could be relieved, the overall performance of the solution would substantially improve. Everything seemed then to hang on one peg. And it did, too. In a linear model the critical constraints at the vertex would always dominate the solution. Yet it should be remembered that no matter what, one is always at a vertex in a linear programming solution. Depending upon the transformation surface at the vertex, the shifts in prices may be relatively larger or smaller than the shifts in quantities.

Since Construction capacity is intrinsically difficult to estimate when carried on as in India with a variety of technologies, initial

capacity in Construction is increased by 5% in Solution T-12 to obtain another test of sensitivity. In this case the scarcity of Cement and Non-Metals is still binding and only a small increase in consumption can be achieved in the first four years.

In Solution T-13 all initial capital availabilities are increased by ten per cent. This, of course, is a drastic change, even more drastic than a ten per cent reduction in the targets. It increases the productivity of the system in all directions at the beginning of the planning period. Overall, it reduces the required rate of growth in capital stocks over the planning period from 7.2 per cent to 5.2 per cent. As a result the total available private consumption increases by about 14 per cent over the Reference Solution and the entire pattern of relative scarcities changes. The targets become so readily achievable that the system can concentrate more of the available resources on the production of consumer goods in order to increase the value of the maximand. The solution achieves in excess of targets in the Agriculture and Plantation, Food, Clothing and Leather, and Housing sectors. The shadow prices, particularly after the first period, indicate that the relative scarcities are highest in the consumer goods sectors.

The initial availabilities are reduced by 10% in case T-14 and no feasible solution can be found with the 96% level of targets.

In Target Solutions T-15 to T-18 capital-output ratios in the Agriculture and Plantations and in the Housing sectors are varied. These sectors not only make important contributions to the consumer budget but their capital-output ratios are relatively large and uncertain. The capital-output ratio in Indian agriculture, for example, has been variously estimated from 1.0 to 2.5. While the capital-output ratio in Housing

depends on the character of the Housing created as well as construction methods used.

In Solution T-15, the capital-output ratio in Agriculture is increased to 2.5 from 1.51. This requires additional investment of about 1500 Rs. crores in order to meet the Third Plan targets. No feasible solution can be found for this case.

Next the capital-output ratio in Agriculture and Plantations is reduced to 1.0 in Solution T-16. The solution provides in this case more agricultural capacity than demanded by the targets. The change in capital stock in Agriculture and Plantations from the first to the sixth year is Rs. 1883 crores as compared to Rs. 2243 crores in the Reference Solution. This reduction in investment in Agriculture is less than half of what it could have been if only the targeted output capacity were met. The lowered investment requirements releases capital goods in the first three years and breaks the Cement and Non-Metals bottleneck. There is no longer excess capacity in all the sectors in the second year. In fact the prices are smoothed out so effectively that the price of 6.72 for Cement and Non-Metals in the second year is the highest price of any good in any period. All this occurs because demand for investment is reduced by the lowered capital-output ratio in Agriculture, which in turn reduces the strain on Cements and Non-Metals. Once the bottleneck is broken, the solution has enough productive capacity to provide even more capacity in Agriculture than is targeted because the objective is increased by doing so.

The capital-output ratio in the Housing sector is the largest in the system. In solution T-17 this ratio is reduced to 7.5 from 10.0. The reduction can be considered as reflecting the uncertainty of estimating

the value and quality of housing and consequently of estimating the capital-output ratio. Moreover Housing is a service whose consumption might as a matter of policy be given a low priority in an attempt at rapid industrialization. To analyze the effects of different priorities, one could lower the targets in Housing and alter the consumption proportions of the composite consumption. However, since Housing is not used as an intermediate product by any sector, a reduced capital-output ratio in Housing has the same effect.[1] Capital in Housing is all in the form of Construction and lowering its capital-output ratio reduces the demand on Construction and consequently on Cement and Non-Metals. Once again this eliminates some idle capacity. In the second year capacity in Agriculture and Plantations is fully used. The consumption growth constraint is now binding only between the fourth and the fifth years. The highest shadow price is now that of Cement and Non-Metals in the third year and is 10.71.

In solution T-18 the capital-output ratios in Housing and in Agriculture are both lowered. The increase in undiscounted consumption over the Reference Solution is Rs. 2627 crores whereas in solutions T-16 and T-17 the increases are Rs. 2317 crores and Rs. 1218 crores respectively. This confirms the interpretation that the changes in both the solutions T-16 and T-17 break the same bottlenecks.

The alternative, lower inventory coefficients in Agriculture, Food, Clothing and Leather products, and Chemicals are used along with lower capital-output ratios in Agriculture and Housing in solution T-19. From the s matrix in Table 3-7 it is seen that reducing the inventory coefficients in these sectors reduces primarily the demand for Agriculture and Chemicals. In solution T-18 the shadow price of Agriculture in the third year is the highest shadow price of any output and is 4.27 which

1 Excepting for the difference in intermediate goods requirements, which are small for Housing.

makes the reduction in demand for inventories of Agriculture especially valuable. Therefore, even though the lowered coefficients correspond to a reduction in investment in inventories of Rs. 860 crores for the five years, the increase in undiscounted consumption over solution T-18 is Rs. 1240 crores.

In addition to the changes in solution T-19, investment lags are also shortened in solution T-20. This solution thus has the most optimistic set of technical parameters investigated and results in the highest levels of private consumption. The shorter gestation lags give enough freedom for the solution to virtually eliminate idle capital as early as in the third year in which less than 0.5 per cent of capital is idle. However, compared with solution T-19, the increase in undiscounted private consumption is only Rs. 949 crores. It was pointed out in discussing solution T-5 that the structure of investment lags was important in determining the character of the adjustments and the overall behavior. Solutions T-17, T-18 and T-19 indicate that this lag structure is relatively unimportant when the bottlenecks are broken by lowered demand for investment goods.

In solution T-21, the shorter set of gestation lags and the lower inventory coefficients are used with the 'standard' capital output ratios. The sum of undiscounted private consumption is Rs. 72435 crores and is Rs. 2227 crores less than in solution T-20. This is comparable to the difference of Rs. 2627 crores between solution T-18 and the Reference Solution, which two also differ from each other only in the capital-output ratios. Thus a lower demand for investment goods, which results from the lower capital-output ratios for the output of capital producing sectors, is

always helpful in these solutions.

The next set of trial solutions, from T-22 to T-30, relates to changes in the availability of foreign exchange due to changes in exports or net foreign capital inflows, which includes foreign aid, and to the allocation of imports. In solution T-22 when the capital inflow is increased by 25 per cent to Rs. 625 crores per year, which amounts to an increase of Rs. 625 crores for the plan period, the sum of undiscounted private consumption increases by Rs. 1624 crores. Thus the productivity of foreign aid seems to be 1624/625 = 2.6. However, this is not necessarily the real productivity of foreign exchange in the Third Plan period. First, as pointed out in other connections the model objective function does not make any allowance for increases in the stream of post-terminal consumption over and above that provided for by the targets. Thus the additional aid may not be put to the uses which would result if such overfulfillments carried some weight. Secondly, the additional aid makes it possible for some of the idle capacities that exist in the Reference Solution to be utilized. However, part of these idle capacities may be the result of assumptions of fixed composition of consumption or of fixed investment lags. To the extent that these assumptions can be modified in reality the decrease in idle capital, which results when additional foreign exchange becomes available, is overstated. Even though idle capacities are not substantial in the Reference Solution, they may be quite important in determining marginal productivity of foreign capital. Thirdly, the savings rates of the model solutions are substantially higher than actually observed and, in these solutions, the value of foreign exchange is lower than if the savings rate were itself constrained to a lower level.

For solution T-22 in which the inflow of foreign capital is increased the shadow prices on the foreign exchange balance constraints for the first three years are higher than the corresponding prices in the Reference Solution. This curious behaviour is the result of the fact that the shadow prices reflect only the value of relaxing one constraint at a time. However, in solution T-22 the foreign exchange availability is changed in all the five years simultaneously and not just one year.

In solution T-24 the inflow of foreign capital is increased by Rs. 500 crores a year to Rs. 1000 crores per year and as a result the private consumption over five years increases by Rs. 3037 crores. Compared with solution T-22, for an additional exchange of Rs. 1875 crores an increase in private consumption of only Rs. 1413 crores is realized. There are two particularly important reasons why private consumption does not increase by at least as much as the additional exchange. Imports are not permitted in all the sectors whose output makes up the composite consumption good. Moreover, the ceilings on competitive imports force imports in sectoral proportions not consistent with the composition of private consumption. This makes it necessary to supplement imports with domestic production not only in the non-importing sectors but also to some degree in most of the importing sectors. In solution T-24 there is more idle capital in all but the second year than in the Reference Solution. This indicates the unfavorable distribution of imports forced by the ceilings on competitive imports.

The effects of reduction in the inflow of foreign exchange is much more dramatic as is seen in solution T-25 where foreign exchange inflow is at Rs. 375 crores per year, a reduction of 25 per cent from the Reference

Solution. This loss in foreign exchange of Rs. 625 crores over five years leads to a reduction in private consumption of Rs. 6098 crores. In T-26 the foreign capital inflow was reduced to zero and no feasible solution could be found. In the conditions of the present solutions aid is a much bigger stick than it is a carrot; when withdrawn, it is more damaging than it is beneficial when increased. Before this is interpreted as demonstrating India's dependence on aid givers or as a support for import substitution policies, the same qualifications have to be recognized as were made in interpreting the productivity of additional foreign exchange. In solution T-25 where aid is reduced there are large amounts of idle capacities in all the three major consumption sectors, Agriculture, Housing and Others and Margin, in the first four years. In the real world where consumption and input proportions are not so rigidly fixed at least some of these idle capacities would have been used to generate additional consumption. However, the fact of these idle capacities is suggestive. The idle capacities in consumer sectors exist because the investment requirements of the targets are so high that they exhaust the capacities in Mining and Metal and in Equipment in order to reach the targets. As a result there is no capacity left in these two sectors with which to make their proportionate contribution to the composite consumption good.

Solution T-27 shows an addition of Rs. 1676 crores in private consumption over the Reference Solution due to the elimination of ceilings on competitive imports. The shadow prices on foreign exchange balance constriants are higher since it can now be allocated to the more profitable uses. The idle capacities are reduced and in the fourth and the fifth years

they are completely eliminated. Yet it does not follow from this result that the distribution of imports during the Third Plan period could have been improved. The distribution of imports enforced in the Reference Solution is not necessarily that which actually prevailed. In addition a different allocation of imports might be optimum for the 96 per cent level of targets than for the 100 per cent level of targets.

In solution T-28 the ceilings on competitive imports are removed and a level of foreign capital inflow of Rs. 1000 crores per year is assumed. The idle capital in this case is greatly reduced as it is no longer necessary to adjust capacities to imports but instead competitive imports at least can be adjusted to capacity. The additional private consumption that is generated by the increased foreign exchange inflow in this case should be compared to solution T-27. For Rs. 1875 crores of additional foreign exchange an increase of Rs. 1973 crores of consumption is obtained in T-28.

In solutions T-29 and T-30 the growth rates for the export projections are varied. Beginning with the same level of exports as in the Reference Solution in the first year, exports are projected for subsequent years at 3 per cent and at 5 per cent annual growth rates respectively in the two solutions as compared to the 4% of the Reference Solution. The lower export growth rate of Solution T-29 corresponds to a fall in exports for the five years of Rs. 47 crores as compared to the Reference Solution and as a consequence a decrease of Rs. 91 crores in private consumption occurs. In solution T-30 for a relative rise in exports of Rs. 76 crores an increase of Rs. 127 crores in private consumption takes place. Even though producing additional exports requires domestic resources, the foreign

exchange earned is more valuable in terms of the objective function. This means that the domestic resources used for exports in fixed proportions are less valuable than the imports which are increased in not quite so fixed proportions.

Estimates made in 1964 are available in the P.P.D. Notes of the levels of output which appeared likely to be achieved in 1965-66. These 1965-66 output levels adjusted on eleven sector basis from Table 3-26 are used as targets in solutions T-31, T-32 and T-33. These solutions cannot be considered as simulating the Third Plan period for several reasons. Among the most obvious is that these 1965-66 output levels are not the targets which were pursued from the beginning of the plan. These levels were reached after a variety of revisions and adjustments including those made necessary by the conflict with China in 1962. For this reason, if no other, one would expect the model solution to perform better than the real world.

Table 4-52 shows the National Income Accounts for solution T-31 where the 'standard' sets of gestation lags, inventory coefficients and capital coefficients are used. The level of private consumption and the gross national product in the first year are 5 per cent and 5.5 per cent above the respective levels in the year 1960-61. The level of private consumption and the gross national product in the fifth year are slightly higher than estimated in the P.P.D. Notes. The gross savings rate in 1961-62 at .1308 is only slightly higher than in 1960-61 at .1270 implied in the I.S.I. input-output table, Table 3-2.

The total investment in the five years is Rs. 17955 crores. However, in the solution, the target for Agriculture has been overachieved and about

Rs. 450 crores of investment need not have been made to reach the estimated level of output. Subtracting an additional Rs. 4500 for replacement this leaves Rs. 13000 crores for net investment. This amount is higher than what was planned in the Third Plan even though the targets are actually lower than the original targets. The investment is also higher than the actual investment achieved during the Third Plan period which has been estimated at around Rs. 9500 crores. The higher rate of investment in the Target Model Solution to achieve a lower level of targets may be due to any one or more of the following possibilities:

(1) The levels of investment calculated in the solution may be in error because the initial conditions and/or terminal conditions have not been correctly stipulated. The arbitrary adjustments which we made in order to achieve full coverage of the 1965 outputs and to stipulate the initial and final amounts of capital-in-process should be recalled at this point. If, as we are inclined to believe, the adjustments tended to overstate each one of these quantities, the amount of investment required in the solution would also be overstated. In solution T-31 investment for the purpose of creating capital-in-process for the early years of the Fourth Plan accounts for Rs. 2295 crores and the solution is endowed with Rs. 1757 crores of unfinished capital at its outset. Underestimation in the latter figure and overestimation in the former would contribute even more to error in the total investment calculation.

(2) The investment calculated in the solution may be overestimated if the real ratios of fixed capital and inventories to output are lower than the ones used in the solution. If lower ratios were used in a solution trial even more private consumption could be provided than in

solution T-31. That would bring the value of the maximand even further above that actually achieved, but, as pointed out, the lower actual level of achievement can be explained by the relative efficiency and foresightedness in the model.

(3) The levels of investment calculated for the levels of output expected to be achieved may be closer to a correct representation of reality than the official projections. The "facts" themselves contain elements of conjecture, and the P.P.D. output and investment estimates for 1965-66 are presented only as "likely" achievements.

(4) The accounting which we use may not be completely comparable to that of the official statistics or the P.P.D. estimates. There is some evidence of non-comparability in the various sources which we have used and we are not confident that this has been entirely eliminated.

Solution T-32 with lower capital coefficients and T-33 with lower inventory and capital coefficients as well as shorter lags indicate even more optimistic performance than in solution T-31.

4.2 Analysis of Third Plan Target Solutions

The alternative solutions to the Target Model for the Third Plan period provide a variety of insights from which we shall now try to extract some summary judgments as to the technical and operational feasibility of the Third Plan Targets.

On the issue of technical feasibility, as defined above, the results can be summarized as follows:

A. The Third Plan targets were technically feasible if

(i) the "shorter" investment lags prevailed,

and if (ii) the "lower" capital coefficients and the "lower" inventory coefficients prevailed,

and if (iii) all other coefficients, parameters and exogenous quantities used are reliable representations of reality.

B. The Third Plan Targets were technically infeasible if

(i) the three year investment lags describe reality,

and if (ii) the "standard" capital coefficients and the "standard" inventory coefficients prevailed,

and if (iii) all other coefficients, quantities and parameters are reliable.

One set of quantities whose significance might be overlooked in the customary concern with capital-output ratios and gestation lags are the initial endowments, the capacities and amounts of capital-in-process. It will be recalled that to establish these we assumed that the outputs of the pre-plan year, i.e. the last year of the Second Plan, represented full use of available capacity, that sectoral capacities grew in the pre-plan year at the average annual rates implicit in the Third Plan targets and that the capital-in-process started in the last two years of the Second Plan was adequate to maintain these growth rates in the Third Plan period itself.

The existence of excess capacity in Indian industry has been a matter of considerable conjectural discussion as have been the issues

related to the phasing of successive Plans. If, in those sectors which were "bottlenecks" in the solutions, there were usable excess capacity or if the initial capital-in-process were underestimated by our procedures, the conclusions above would have to be modified. The exact amount by which these initial conditions would have to change in order to affect the outcome of the solutions would again depend on the other coefficients and parameters assumed.

The data available to us do not permit a more definitive judgment on these issues. It is worth noting, however, that, if our assumptions as to initial conditions are warranted, then 25 per cent of the total net investment programmed during the Second Plan would have been for the purpose of creating capacity which would have been used only during the Third Plan. Based on this and more general and intuitive impressions we believe that our errors with respect to initial conditions have been in the direction of over- rather than under-estimation.

Even if the issue of technical feasibility is decided favorably, all the problems of operational feasibility remain. We shall not enter here on questions of the adequacy of the organizational structure to implement the plan or the availability of the required skills of all types. Though we emphasize their importance in a comprehensive evaluation, our technique tells us nothing on such matters. It does, however, yield information on another crucial aspect of feasibility: the investment and savings required to realize the targets.

Table 4-53 summarizes four estimates of total investment requirements. Shown first are the official estimates of the Third Five Year Plan document, which, on a net basis, comes to Rs. 10,400 crores of which Rs. 9,600 crores

was fixed and Rs. 800 crores was inventory investment. We could not find a comprehensive estimate of replacement requirements.[1]

The second estimate in Table 4-53 applies a conventional technique of multiplying projected increments in output in each sector by a sectoral capital-output ratio and summing. This appears to have been a commonly used procedure in preparing the Indian Plans. Line 2.1 is the conventional capital-output ratio calculation of investment requirements. It contains an adjustment to obtain the investment requirement for the actual plan period. First the capacity on hand at the beginning of the plan period was greater than that which produced the output levels of the pre-plan period, $X_i(0)$ by the amount of investment which matures during the pre-plan period. Secondly, the capacity on hand at the end of the plan will be greater than that which produces the target output levels of the fifth year by the amount of investment which matures only at the end of the last year and is not available for production during the last year. The adjustment is made by applying the growth rate implicit in the Plan to each of the output levels. Lines 2.2 and 2.3 add the net investment in fixed capital in process during the plan in order to calculate total net investment in fixed capital. With the inventory investment calculated in line 2.5 it adds up to total net investment in line 2.6. When replacement is added the total gross investment is given in line 2.8.

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1 An estimate of Rs. 150 crores was made for the industrial sector as a whole as a projection of the replacement carried out in the Second Five Year Plan period. However, this was admittedly less than the replacement requirements estimated for the cotton, jute and woolen textile industries alone. See Third Five Year Plan, p. 460.

The third set of estimates in Table 4-53 is taken from two solutions, the Reference Solution for the 96% level of Third Plan targets and solution T-31 with the 1965-66 likely achievement estimates. It can be seen that these estimates are roughly the same as those based on the projected increments in output and the use of capital-output ratios. The small differences are due to the fact that in the solutions replacements are sometimes not made whereas on line 2.7 they are all assumed to be made. However, the model solutions provide complete details on the sectoral amounts, timing and uses of investment.

It may be recalled that the investment estimates of the Target Model are to a considerable degree independent of the optimizing mechanism. The calculation of the investment required solely to meet the plan output targets does not depend on the optimizing mechanism in any way and can be regarded as taking place independently. The distribution of that investment over the planning period will be directed by the optimizing mechanism in a manner which will permit the maximum amount of consumption to be produced with the given resources. If at all possible, it will generate additional investment to further increase capacity in order to produce additional consumption goods. In the Reference Solution, however, the constraint of meeting the targets is so great as to allow the solution virtually no opportunity to divert resources to producing even more investment than stipulated by the targets in order to increase consumption goods output. In addition the solution to the Target Model might call for more investment than a simple incremental calculation such as that of line 2.3 in Table 4-53 would indicate if the sectoral composition of the targets is "imbalanced." That is, the targets may stipulate a level of

output for one of the capital producing sectors which is below the actual levels needed if the other sectoral targets are to be achieved. That, in fact, appears to be the case in Construction in the Reference Solution. However, the overachievement in Construction is quite small.

The second and third sets of estimates in Table 4-53 show investment requirements which are higher for the 96% level of targets, than the planned investment for the 100% level of targets. The differences may arise due to discrepancies in any of the elements in the computations. We have mentioned the problems in estimating initial conditions. There are similar problems in estimating terminal conditions. The Plan calculations may have used different capital coefficients and this in turn might be due to its projection of increasing returns not embodied in our linear model.

The differences may also reflect some incomparability in the estimates of the plan and of the target solutions here as was suggested by solution T-31 with the P.P.D. estimates of 1965-66 likely outputs as targets. The 1960-61 gross savings rate in the I.S.I. input-output table, Table 3-2, is 12.8%. Net savings-income rate for the period 1961-63 is estimated by the Reserve Bank[1] at 9.5%. However the P.P.D. Notes give for 1960-61 a gross savings rate of 9.9%.

Whether the savings required are higher than planned or not, the savings rates increase over the plan years and would require special efforts to realize them. Among the lessons to be learned from the solutions is an enhanced appreciation of the difficulties of coming to judgments about a plan when complete specifications are not available and

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1 See Reserve Bank of India Bulletin, March, 1965, p. 327.

the facts themselves are debatable. Though the Target Model calculations raise doubts as to the technical and operational feasibility of the Third Plan targets we would stress again the tentative character of the results.

4.3 Target Model Solutions for a Set of Proposed Fourth Plan Targets

4.3.1 Assumptions for the Fourth Plan Target Solutions

A set of targets for the Fourth Five Year Plan were proposed by the Perspective Planning Division of the Indian Planning Commission in Notes on Perspective of Development, India: 1960-61 to 1975-76.[1] These will be the subject of the next set of solutions and analysis. It should be emphasized that the proposals contained in the Notes were for discussion and did not represent a final and officially adopted set of targets for the Fourth Plan period. Yet the Notes contain the only set of proposed Fourth Plan targets which were published which is sufficiently comprehensive to form a basis for analysis.[2]

The analysis of the Fourth Plan Targets proceeds along lines similar to the analysis of the Third Plan and, since the results are generally similar in character, can be summarized more briefly. This analysis is even more tentative than that for the Third Plan, however, as neither the initial conditions nor terminal targets can be as firmly specified. Most of the information on initial conditions and targets are taken from the Notes. The initial conditions, that is, the set of capacities and capital-in-process at the beginning of the Fourth Plan period, are

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1 April, 1964.

2 Subsequently the beginning of the Fourth Plan was postponed and presumably in these changed circumstances the targets in the Notes would no longer be recommended for the Fourth Plan. The Fourth Plan Period referred to here is the one originally foreseen, 1966-67 to 1970-71.

more provisional than in the case of the Third Plan as final estimates for the Third Plan period were not available at the time of writing. Furthermore, the P.P.D. Notes estimates of outputs of the "organised" parts of the sectors are adjusted in a manner which has essentially arbitrary elements due to lack of information to obtain a more complete coverage consistent with the input-output matrix. This adjustment is carried out on an eleven-sector basis as well as on a thirty-two sector basis. Thus we have two alternative sets of tentative initial and target levels of outputs.

It will again be convenient to conduct the exposition in terms of a Fourth Plan Reference Solution and alternative Fourth Plan solutions with changes in parameters. The following data are used for the Reference Solution.

(1) The technical coefficient matrices a, b, s, p', p'', p''', r', r'' and r''' are assumed constant throughout the plan period and are those presented in Chapter 3 as the reference values.

(2) The consumption coefficient c(t), non-competitive import coefficients m' and competitive import ceilings m'' are also assumed constant throughout the plan period.

(3) Requirements of $\overline{E}$, $\overline{G}$ and $\overline{D}$ are exogenously specified at the levels shown in Tables of Chapter 3.

(4) Net foreign capital inflow is fixed at a constant value of Rs. 500.0 crores per year.

(5) A social discount rate of 10% is used for private consumption in the objective function. i.e. $w = 0.10$.

(6) The minimum growth rate of consumption $\rho(t)$ is set at .025 (i.e. 2.5%) for all the periods. However, $\overline{C(0)}$ is set at zero.

(7) The initial output $\overline{X(0)}$ and the terminal year output $\overline{X(5)}$ are the P.P.D. Notes 1965-66 and 1970-71 estimates adjusted for coverage on the eleven-sector basis from Table 3-26.[1] The initial and terminal growth rates are the implied growth rates between these $\overline{X(0)}$ and $\overline{X(5)}$.

Once again it is pointed out that the Reference Solution should not be considered as our best guess as to the Fourth Plan nor as one embodying all the assumptions of the Fourth Plan targets as set out in the P.P.D. Notes.

4.3.2 The Reference Solution

A feasible solution was obtained for the Fourth Plan targets and parameters as described in the preceding section. The Reference Solution is presented in Tables 4-54 through 4-73.

The sum of undiscounted private consumption over the five years from 1966-67 through 1970-71 is Rs. 80311 crores and the sum of discounted consumption is Rs. 66664 crores. The P.P.D. Notes estimates of undiscounted private consumption for this period is about Rs. 90000 crores. However, in the Reference Solution there are substantial excess capacities in all the sectors in the third and the fourth year. These excess capacities resulting from certain rigidities in the production and consumption structure of the model might in reality be used to provide more consumption if the rigidities can be overcome.

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1 These will be referred to as the Fourth Plan targets recognizing, as pointed out above, that they are in their source, not official, and have been further adjusted by us.

An overall guide to the details of the Reference Solution is provided by recognizing that, in this case, the availability of foreign exchange rather than domestic capacity sets a limit to the domestic output which can be produced in the last year of the plan. In this year as shown in Table 4-71 there are no competitive imports because all the foreign exchange available is required for non-competitive imports which are determined by domestic output levels, and these levels are less than domestic capacities. It should be noted that the non-competitive import coefficients used in the Reference Solution are kept constant at the level of their 1960-61 values. If the import substitution program which is implied in the P.P.D. Notes were successful in changing the non-competitive import coefficients, the limits imposed on the domestic production by the availability of foreign exchange could be extended.

In this case as in the Third Plan case Mining and Metal, Equipment, and Chemicals are planned to be the fastest growing sectors while the planned growth of the predominantly consumers goods sectors is at a lower rate. This is seen both in Table 4-54 which presents Gross Domestic Outputs and Table 4-57 which presents the Available Capital Stocks. On the whole the shadow prices on output in Table 4-55 also reflect this relative emphasis but we shall return later to this table to explain some of the more striking features of the solution.

From Table 4-56 which shows the details of private consumption for the five years, it is seen that the consumption growth constraint is binding for all the four years. This is an outcome not of a flip-flop tendency to concentrate consumption at the beginning of the plan period but of the fact that the capacity to produce private consumption in the fifth year is

limited by the availability of foreign exchange. The consumption growth constraints, acting backwards, then restricts the private consumption in the first four years. This interpretation is supported by the presence of excess capacities in all the sectors in the third and the fourth years as shown in Table 4-59.

Within the limits of the given availability of foreign exchange in the fifth year the solution adjusts the composition of the output by altering the amounts of investment and consumption in each period to ameliorate the effects of this constraint.

Tables 4-57 to 4-61 which summarize the formation, availability and use of capital throw considerable light on the determining forces in the solution. There is capital formation in all periods as shown by Table 4-57 but not in all sectors in every period. For example, in Mining and Metals, Equipment, Chemicals, Food and Clothing, and Electricity the capital available in the fourth and fifth periods is the same. There is even decumulation in Housing, and Other and Margin in these periods and in Mining and Metals, Food and Clothing, and Transportation in the sixth period. The tables indicating the use of capital show substantial excess capacities in every period and, contrary to what one might expect, the absolute and relative amounts of idle capacity actually increase in many sectors in the third and fourth years. These features suggest that with the given conditions it is preferable in many sectors to concentrate on capital formation at the beginning of the plan period and to have this capital idle in the fourth and fifth years rather than to spread the new capital formation to achieve the targets more uniformly over the plan years.

The shadow prices of outputs in Table 4-55 reflect these adjustments in the solution to minimize production for fixed investment in the fifth year. The highest shadow price in the entire plan period is 64.83 for Mining and Metals in the second year when its capacity is fully utilized. Mining and Metals is one of the major inputs to Construction. An additional unit of output of Mining and Metals in the second year would have made it possible to start additional investment to mature at the beginning of the fifth year in the form of Construction since Construction has idle capacity in the second year. Furthermore, since there are idle capacities in all the sectors in the third and fourth year and foreign exchange is not an absolute bottleneck this investment started in the second year could be completed. The importance of Construction in the second year is also indicated by its shadow price which is the second highest in that year.

The shadow rental prices confirm the earlier interpretation of shadow prices of outputs. So do the idle capitals in Table 4-59. The idle capacities in the third and the fourth years cannot be used in the production of either consumption or investment. The consumption growth constraints would require additional consumption in the fifth year. Investments started in the third or the fourth year have to be supplemented with additional investments in the fifth year. Neither can be provided due to the foreign exchange limitation.

The idle capacities in the first and the second year cannot be used to generate additional investment due to the shortage of capacity in Mining and Metals. The bottlenecks of Mining and Metals cannot be broken by imports due to the ceilings on competitive imports.

The high shadow prices of the output of Mining and Metals, and of Equipment in the third period are striking. Since there are excess capacities in all sectors there are no bottlenecks to be broken. However, an additional unit of output of either of these in the third year would mean that the domestic production in the third year can be lowered by one unit. This in turn reduces the required investment for inventories in the second year releasing Mining and Metals for other uses. Other sectors with high requirements of Mining and Metals for inventories also show high shadow prices in the third year.

The high shadow prices for the outputs of the Mining and Metals, Equipment, and Chemicals sectors in the fifth year are due to the high coefficients of non-competitive imports in these sectors. An additional unit by lowering the domestic production would release foreign exchange which could be diverted towards production of more consumption.

The solution provides more capacity in Mining and Metals than is required by the targets. Furthermore, all this capacity is used in the fifth year. This may indicate a possible shortage of Mining and Metals in the post-terminal year especially since Mining and Metals are used primarily as inputs to Construction and Equipment and since the solution is trying to minimize investments in the fifth year. However, the terminal inventory stocks to be provided at the end of the plan correspond to the target stocks of the sixth year and since the inventory stocks in the fifth year are small because of the lower domestic outputs, a larger investment in inventories is required in the fifth year than would be the case if foreign exchange were not a bottleneck.

The initial capital in process in Table 4-62 is completed in all the sectors except Housing in the third year. Housing has the lowest shadow price of new capital in the third year in Table 4-65.

In Table 4-64 the new capital that matures in each year is shown. No capacities are created to mature in the sixth year in Mining and Metals, in Food, Clothing and Leather, in Transport and in Construction, and the last three sectors have idle capacities in the fifth year. Once again this behavior indicates that the solution has tried to reduce the investment undertaken in the fifth year.

Tables 4-69 through 4-72 show the details of imports. The shadow prices on the competitive import ceilings in the fifth year are non-zero even though there are no competitive imports. When all the exchange is used up for non-competitive imports, the import ceilings are binding for all the sectors as the ceilings now take the form of $[m']^{-1}M'(5) \leq 0$. The shadow price on the balance of trade constraint for the fifth year is the same as the shadow price of Others and Margin which has the lowest shadow price among all the sectors in which imports are permitted.[1]

As pointed out in the preceding discussion, the ceiling imposed by non-competitive import requirements in the final year not only affects

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1 The negative shadow prices for competitive import ceilings on Others and Margin in the first and the second years are due to numerical round-off in the computer program. By setting the tolerance limit in the program more stringently, the negative prices could have been eliminated. These negative prices lead to a slight distortion in the allocation of competitive imports in these years and the model solution imports Others and Margin. Since these imports are small and would have been otherwise allocated to Agriculture and Plantation, and since there is idle capacities in both the sectors in both the years, the effect of correcting the tolerance would have been small. Consequently, the computer program was not rerun.

output in that year but has an effect throughout the plan period as the solution makes an optimal adjustment to it. The non-competitive imports which would be required in the sixth year if all the targeted capacities could be fully utilized, amount to Rs. 2768.24 crores. This is Rs. 925.0 crores or 50 per cent more than the previous year. While there is no guarantee that such full utilization would be possible it again suggests the importance of achieving the import substitution program of the P.P.D. Notes and changing the non-competitive import coefficients accordingly. These coefficients are changed in an alternate run described in the next section. However, it should also be kept in mind that the need for non-competitive imports is itself a function of the size and composition of the targets.

Table 4-73 shows the National Income accounts for the Reference Solution. Achievement of the gross national product of Rs. 30725 crores in the fifth year represents an exponential growth rate of 8.5 per cent over the gross national product of the first year of Rs. 22172 crores. The total gross investment required is Rs. 35037 crores. Just as they were understated in the Third Plan Reference Solution, the replacement requirements are also understated in Table 4-73 and the net investment requirements overstated to the extent that restoration and new capital creation are undifferentiated in the solution. The replacement requirements amount to about Rs. 5000 crores. The net investment required over the Fourth Plan period is then Rs. 30000 crores. The inventory change in the first year is negative and inventories are decumulated. This happens because the initial inventories correspond to the full capacities whereas the solution has substantial idle capital in the first year. However, the

terminal inventories have to correspond to the target stocks. Consequently the decumulation in the first year has subsequently to be made up and the total requirements over the plan years of investment towards inventories remain unchanged at Rs. 4762 crores.

If the idle capacities in the Reference Solution could be employed by suitable variation of the coefficients, the gross savings rates in Table 4-73 would be reduced due to additional income which would be generated. The calculations of investment requirements, however, are not affected by idle capacities since they depend on the initial and the terminal capitals completed and in process, and on the aggregate inventory/output and capital/output coefficients.

4.3.3 Alternative Fourth Plan Target Solutions

The Fourth Plan Target Reference Solution though in general similar to the Reference Solution for the Third Plan Targets differs in many details. Likewise, it cannot be assumed that the alternative solutions with variations in parameters for the Third Plan targets provide exact predictions of the effects of similar variations in the Fourth Plan context.

The first calculation is one outside the model structure in which it is arbitrarily assumed that all the idle capacity of the Reference Solution can be utilized by whatever variation of input proportions is necessary. The additional output thus generated is allocated to consumption and other uses in the proportions of the fifth period of the Reference Solution to allow for uses of the additional output as intermediate inputs, for inventory accumulation, etc. The total additional output of consumption goods which is generated in this way is Rs. 15,500 crores, and provides a

rough and generous adjustment to offset the rigidities in the assumptions of fixed production and consumption proportions. This amount, added to the undiscounted consumption of Rs. 80,311 crores of the Reference Solution, provides a total consumption of Rs. 95,811 crores which is higher than the Rs. 90,000 crores estimated in the P.P.D. Notes.

Turning to the alternative calculations, which are shown in Table 4-74, the solution F-1.1 shows the effect of increasing the minimum annual growth rate of private consumption from 2.5% to 5.0%. This growth rate of consumption is achieved by depressing the level of consumption in the early years. Interestingly, the shadow prices on the consumption growth constraints in all the years are lower in this case than the corresponding shadow prices in the Reference Solution even though the constraints are made more stringent. This is possible because several constraints are modified simultaneously and because when the consumption growth rate is changed, the constraint planes $C(t+1) - (1.0 + \rho(t))C(t) = 0$ do not move parallel to themselves but instead change their slopes.

In solutions F-1.2, F-1.3, and F-1.4, net foreign capital inflow is increased. An increase of 25% to Rs. 625 crores per year is not sufficient to relieve the non-competitive import bottleneck in the fifth year though aggregate consumption rises by 12%. The bottleneck is broken, however, when net foreign capital inflow is increased by 50% to Rs. 750 crores per year and there are some competitive imports in the fifth year in F-1.3. Solution F-1.4 has the net foreign capital inflow increased only in the fourth and the fifth years and the overall performance is even better than that of solution F-1.2 in which there is a larger total inflow. Once the import bottleneck is broken, the major consumption goods sectors show

higher shadow prices than the investment goods sectors in the fifth year.

In order to investigate directly the significance of import substitution, solutions F-2.0, F-2.1 and F-2.2 are carried out with decreasing coefficients for non-competitive imports as shown in Table 3-16. In solution F-2.0, the non-competitive imports are no longer binding. Mining and Metals still has the highest shadow price but is reduced to 12.96 in the third year from the second year high of 64.83 in Reference Solution. However, Agriculture capacity is now used in all the periods and, in fact, restricts aggregate consumption in the first four years. The consumption growth constraint is not binding in any year and a growth rate over the plan period of nearly 7% is obtained for private consumption. Solution F-2.2 is in general similar to solution F-1.4 and the difference in undiscounted private consumption is only Rs. 929 crores, of which Rs. 375 crores may be accounted for by difference in foreign capital inflows. Solutions F-2.1 and F-2.2, in which net foreign capital inflows are lowered, indicate that in this case the targets are technically feasible even when net inflows are reduced substantially. There are even considerable amounts of idle capacity in these solutions which could generate additional consumption if the composition of private consumption and/or input proportions were varied. All these solutions show a high shadow price for Mining and Metals in almost all years. Furthermore these solutions provide more capital in Mining and Metals in the sixth year than is targeted. Since Mining and Metals is a major supplier to both the capital producing sectors, Equipment and Construction, the implication is that the production of the investment necessary to meet the targets requires more Mining and Metals than is targeted.

In solution F-2.2 idle capital exists in all the sectors in the fourth year and the consumption growth constraint is not binding between the fourth and the fifth year. The capacities in the fourth year could not be used for producing additional private consumption because the corresponding inventories in the form of Mining and Metals could not be produced in the third year.

Solution F-3.0 shows the effects of using the alternative, lower inventory coefficients. As a result the total investment required for inventories decrease from Rs. 4762 crores to Rs. 3124 crores. This reduction of Rs. 1638 crores in investment requirements alters the solution significantly. Much more consumption is produced. Though non-competitive imports are still a bottleneck in the fifth year, they are not as significant as in the Reference Solution as indicated by the fact that consumption growth constraint is binding only between the fourth and the fifth years. The shadow prices on Mining and Metals are reduced and capacity in excess of the target amount is no longer created in Mining and Metals even though the inventory requirements in the form of Mining and Metals is not smaller than in the Reference Solution.

The reduction in inventory coefficients may be regarded as the result of increased efficiency in distribution. The rather substantial increase in consumption which results indicates still another way of alleviating the bottlenecks associated with a particular set of targets. Inventories in the model serve as shock absorbers to fluctuations of demand and supply but to only a limited degree because of the fixed coefficients.

When the capital output ratio is decreased in Agriculture from 1.51 to 1.0 and used with the set of lower inventory coefficients in solution F-4, the total investment requirements are reduced by Rs. 1622 crores. The targets now can be attained easily and the solution already reaches target capacities in four sectors by the fifth year. The shadow price of Mining and Metals ~~is~~ not the highest shadow price any more. Instead, Food, Clothing and Leather has the highest shadow price. In this case the shadow prices reflect mainly the problems of increasing the objective function.

When the capital output ratio in Agriculture is raised to 2.5 in solution F-5 as a way of indicating the difficulties of expanding output in that sector, private consumption available is reduced by 15% as compared to solution F-3.0. The consumption growth constraints now are binding in all the years. The non-competitive import coefficients are a bottleneck in the fifth year and more than 15% of the capacity is idle in each of the first four years. Idle capacity in the fifth year is 9.5% of the total capital stock. The shadow price of Mining and Metals is high in all years and is 73.8 in the third year. Furthermore, more capacity is created in Mining and Metals than is required by the targets.

The solutions F-3.0, F-4.0 and F-5.0 demonstrate the sensitivity of the model solutions to changes in investment coefficients and, therefore, to total investment requirements. This sensitivity is accentuated by the assumptions of fixed coefficients and compositions. However, to the extent that these coefficients cannot be varied from year to year without cost, these results are an indication of the strains and scarcities that may be generated with different investment requirements.

In solution F-6.0, as compared to F-4.0, in addition to lowering the capital-coefficient in Agriculture, the capital-output ratio in Housing is also reduced. This has a small effect and the private consumption increases only by Rs. 1027 crores because capital in Housing consists entirely of Construction and Construction is not a bottleneck in these solutions. Non-competitive imports are binding in the fifth year.

Solutions F-6.1 through F-6.5 explore the effects of different availabilities of foreign exchange when the set of lower inventory and capital coefficients prevail. The import bottleneck is broken in solution F-6.2 when net foreign capital inflow is increased to Rs. 750 crores per year. Solution F-6.2 can be compared with solution F-1.3 to estimate the effect of lower inventory and capital coefficients when the non-competitive import bottlenecks in the last period are broken by additional foreign aid. The private consumption goes up from Rs. 91448 in F-1.3 crores to Rs. 98610 crores in F-6.2, an increase of Rs. 7162 crores, whereas the difference in total investment requirements is Rs. 2897 crores.

Solution F-6.3 in which net foreign capital inflow is doubled shows an increase of Rs. 974 crores in private consumption over solution F-6.2 even though the additional foreign exchange amounts to Rs. 1250 crores. As was pointed out for the Third Plan target solutions, this is an outcome of the competitive import ceilings, fixed composition of consumption and the lack of incentive to the model solution to provide more capacity than called for by the targets. These conditions lead to a waste of resources and in the solution in the first year, Mining and Metals is produced domestically, is imported and is thrown away as there is no use for it. In this way the solution saves on production of inventories in the first

period by reducing the increment of output of the second period over the first period. This is desirable whenever the saving on inventories is greater than the cost of producing them.[1]

When net foreign capital inflow is reduced to zero in F-6.5, the targets are still feasible with the lower capital and inventory coefficients. Non-competitive imports are now a bottleneck to domestic production in the second, third and fifth years. There are idle capacities in all sectors in the third, fourth and fifth years and on an average 55% of the capital stock is idle in each year.

Solution F-7.0 has shorter lags in addition to the lower coefficients of solution F-6.0 and solutions F-7.1 through F-7.3 indicate the effects of varying net foreign capital inflow with these conditions. The effect of shorter investment lags can be appreciated when solution T-7 is compared to solution F-6.0. Solution F-7.0 provides Rs. 4962 crores of additional consumption, produces more gross national product as well as generates more total investment.

Adjusting the P.P.D. targets for the organized sector to cover the unorganized sector on a thirty-two sector level of disaggregation results in higher targets and initial conditions. These are used in solutions F-8 through F-8.17 With these conditions larger amounts of investment are required than in solutions F-1.0 through F-7.0 even though the initial capacities are higher.

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1 The solution in a sense is transforming current inputs, $a_i x_i$, into inventories, $s_i x_i$. $s_i x_i$ may be preferred if at least one coefficient of column s_i is greater than the corresponding element of column a_i.

The general characteristics of solutions [illegible] are similar to those of the Preferred Solution. Non competitive [illegible] exhaust all the [illegible] output. The larger investment demand in the [illegible] required to meet the larger resource [illegible] and further [illegible] consumption in the [illegible] year. The consumption growth continues [illegible] growth rate of [illegible] and the consumption [illegible] were lower. [illegible] shorter supply and have higher [illegible] [illegible] competitive [illegible] [illegible]

[illegible]

[illegible] factors for [illegible] Their growth [illegible] Furthermore, [illegible] The lower [illegible] growth rates result [illegible] learning capital stock [illegible] the [illegible]

amounts of capital-in-process as well as terminal inventories are also lowered and the required gross investment falls to Rs. 34478 crores as compared to Rs. 39170 crores in solution F-8.0. This reduction of Rs. 4692 crores in the investment demand is sufficient to break many bottlenecks and the private consumption goes up from Rs. 45082 crores in solution F-8.12 to Rs. 87148 in solution F-8.17.

4.4 Analysis of Fourth Plan Target Solutions

The Fourth Plan targets which have been analyzed are projections based on the targets presented in the P.P.D. Notes rather than those of the Notes, itself. The distinction must be kept in mind since judgment of the feasibility of the latter targets involves another conjectural step.

The solutions to the Target Model indicate that the targets are technically feasible under a wide variety of assumptions as to coefficients, parameters and exogenous quantities. This suggests to us that the P.P.D. targets themselves would be technically feasible since the adjustments made are not uniformly, and we think not extremely, favorable or unfavorable.

The sectoral detail of the Target Solutions is also useful in exploring issues of feasibility. For example, in all solutions in which the reference set of inventory coefficients are used, more capacity is created in Mining and Metals than called for by the targets. These coefficients which we believe to be optimistic may be much too low, at least for the industrial sectors.[1] It would seem then that provided no excess

1 Economic Weekly, December 1965, reports that 22 large public enterprises carried inventories amounting to the output of a year or more. This means an inventory coefficient of 1.0 or more -- closer to A. K. Sen's estimates.

capacity in Mining and Metals exists in 1965-66, and provided that our adjustments of targets for coverage have not distorted the demand for Mining and Metals, a shortage of Mining and Metals should develop unless the target for Mining and Metals is increased.

Furthermore, if non-competitive import coefficients are maintained at their 1960-61 levels imports of intermediate goods would form a bottleneck in the fifth year i.e. in 1970-71 unless net foreign capital inflow is increased in that year. The non-competitive import coefficients may remain at their 1960-61 levels if import substitution program is not adequate or successful in meeting by domestic production the increased demand for intermediate goods imports that is likely to accompany rapid and varied growth of industries.

The issues related to operational feasibility are more difficult to resolve. We shall again concentrate on the question of investment and savings and refer to the total gross investment estimates presented in the last column of Table 4-74 and in Table 4-75. Table 4-75 presents the P.P.D. Notes estimates and incremental calculations under various assumptions. For the most part the solutions indicate substantially higher levels of investment requirements for the adjusted targets than projected in the P.P.D. Notes for the targets there. With the same levels of net foreign capital inflow this would mean higher levels of domestic saving. The average and marginal savings rates implied in the solutions are at levels which would imply relatively large changes from recent Indian experience. Yet the changes in savings which have taken place in recent years would also have to be regarded as relatively large. So one could not conclude that the implied savings and investment rates are

necessarily unachievable particularly since the solutions also indicate the potential of relatively high rates of growth of per capita consumption. Yet the savings and investment rates which have actually figured in Fourth Plan discussions are slightly less than those implied by the most optimistic solutions, Column 4, Table 4-75. It is unlikely that the required rates could be achieved without explicit government policies being prepared and vigorously pursued.

To move to judgments about the P.P.D. targets themselves requires an assessment of the adjustments which were made and the other assumptions as to initial conditions. Our technique of setting initial conditions by assuming a conscious phasing of the Third and Fourth Plans again seems to us to be somewhat optimistic. There is relatively little evidence that this has been done, yet the potential achievements of the first plan years and, therefore, of the entire plan are crucially dependent on the amount and composition of the capital in process started in the previous plan. If excess capacity in industry, of which there have been persistent reports, could be utilized, it would offset inadequacies in phasing. The adjustment to extend the coverage of the explicit P.P.D. targets when carried out on an eleven-sector basis implies much lower aggregate targets than when done on a thirty-two sector basis. If the Fifth Plan growth rates of the P.P.D. Notes are used to set post-terminal conditions that implies lower growth rates in all sectors and discontinuities in many. With these conditions imposed the adjusted targets still require much more investment than projected by the P.P.D. Notes with our reference set of parameters and coefficients.[1] If these parameters can be made more favorable including,

1 Which are not those used by the P.P.D..

for example, achieving a lower effective capital-output ratio in agriculture, the Target Model calculations of investment requirements can be brought into general alignment with the P.P.D. Notes estimates. Overall, in our judgment operational feasibility of the P.P.D. Fourth Plan output targets, in the special sense of consistency of these targets with the investment and savings program, requires relatively optimistic projections of the productivity of capital and the ability to direct resources into the organized sectors.

4.5 Transit Model Solutions

The Transit Model has only a limited amount of interest for short term planning. Its endogenous procedure for setting targets -- which guarantee the attainment of exogenously stipulated post-terminal growth rates -- makes it an open-ended model as compared to the Target Model in which both initial and terminal conditions are stipulated. This procedure endows it with foresight, but to only a limited degree. Beyond the post-terminal periods which must enter the plan explicitly due to gestation lags it cannot provide for changing the composition of consumption except in a predetermined manner or for varying its rate of growth. As in the Target Model, the targets enter the system as constraints rather than as part of the objective function. This is equivalent to an objective function which has infinite weights on terminal capital stocks up to the point of their satisfying the target constraints and beyond that no weight at all. Though this limitation might be overcome by repeated trials with different terminal conditions, the shortness of the period over which optimal adjustment can occur remains a major deficiency which is corrected only in the long term, Guidepath Models. The Transit Model solutions are worthy of attention,

however, as contrasts to the Target Model solutions. By generating and adjusting to targets whose level and composition are substantially different from those for the Third and Fourth Plan period, the Transit Model provides additional insights into the Target Model solutions and the economy. We shall present Transit Model solutions only for the Fourth Plan period since the quality of the solutions for the Third Plan period is generally similar. At the risk of being repetitious we again warn that no one of the Transit Model solutions can be accepted as necessarily representing the best of all possible paths for India to take.

To carry out the Transit Model computations initial capacities and capital-in-process must be specified. These initial conditions are taken from those specified for the Target Solutions. That is, it is again assumed that in the pre-Plan period preparations were made to achieve those targets which were actually stipulated in the Plans. This starts the solutions in the direction of the plan targets but now it is up to the model to decide if it wishes to continue in that direction. In place of the stipulated target outputs only post-terminal growth rates are specified exogenously in each of the sectors for private consumption, government consumption, exports and imports. The stipulated annual post-terminal growth rates are as follows:

Consumption	5.0%
Government	2.5%
Exports	4.0%
Imports	3.0%

The fixed and inventory investments necessary to maintain these rates are determined by equations (14.0) and (14.1) of Table 2-2 of Chapter 2

simultaneously as part of the optimum solution for the plan period.[1]

The salient features of the solutions to the Transit Model which were computed for the Fourth Plan period are shown in Table 4-76. A glance at the table and comparison with Table 4-74 indicates that the values of consumption made available in these solutions are uniformly higher than in the Target Solutions with comparable specifications of parameters. The levels of gross national product achieved in the fifth year are roughly comparable but the amount of gross investment undertaken during the plan period in the Transit Model solutions is usually only somewhat more than half that in the Target Model solutions. This latter observation goes far toward explaining the higher values of the maximand in the Transit Model solutions.

It is again convenient to carry out the presentation mainly in terms of a Reference Solution and variations on it.[2] Table 4-77 shows the sectoral output in each year for the Reference Solution. In the Transit Model case total output grows less rapidly overall but more rapidly in Agriculture, Food and Clothing, and Housing, the major consumer goods

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1 There are slight discrepancies in the specification of initial conditions and in the a and s matrices used in the Transit Model solutions for the Fourth Plan period as compared to those used for the Target Model solutions. As a result differences in the maximands are not precise measures of the effects of the alternative terminal conditions though these remain the most important source of the contrasts in the solutions. This qualification reinforces the caveat that the quantitative differences observed in the solutions should not be interpreted as precise forecasts.

In addition the initial conditions for the Transit Model were taken from those for the Fourth Plan Target Model solutions when the P.P.D. targets were adjusted on a thirty-two sector basis.

2 In the Transit Model Reference Solution the minimum intra-plan annual consumption growth rate is 2.5% and the discount rate is 10%.

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sectors, than in the Target Model Reference Solution. The rates of growth in Electricity and Transportation sectors are about the same in the two Reference Solutions but the rates of growth in the capital goods sectors and their major suppliers, Mining and Metals, Equipment, Chemicals and Cement, Glass and Wood are much higher in the Target Model Reference Solution. Interestingly, in the Transit Model solution output in the first two of these sectors actually declines during the plan period. This happens after the inherited capital-in-process which needs only the last dose of investment is finished up in most sectors. The endowed capital-in-process which requires two years to finish is not completed in the capital goods and closely related sectors and the total demand for their output falls even though demand for capacity in other sectors and for inventories is increasing.

The shadow prices of output in Table 4-78 are lower and generally more uniform in the Transit Model than in the Target Model Reference Solution. They are higher in the consumer goods sectors rather than in the capital goods sectors and their major suppliers. This indicates a greater degree of correspondence among the objective function, the initial endowments and the terminal targets endogenously generated in the Transit Model. This, it should be emphasized, is not necessarily a virtue, but reflects all the issues associated with the determination of the targets themselves.

Consumption as shown in Table 4-79 starts from a higher level, and after being constrained by the consumption growth requirements until period three, grows by 17% and 20% in periods four and five.

The higher levels of consumption and related lower levels of saving lead to lower levels of capital accumulation as shown in Table 4-80 as compared with the Target Model Reference Solution. Since both models start out with the same capital endowment they end up with substantially different final capacities. In the Transit Model Reference Solution the capital on hand at the end of the plan period is Rs. 51,732 crores. In the Target Model case, the corresponding total is Rs. 60,579 crores, a difference of 17% which is about the same as the percentage difference in the total amounts of consumption made available. In examining Table 4-80 it is useful to recall that in setting initial conditions it was assumed that the Indian economy had in the pre-Plan period actually been directed toward achievement of the next Plan's goals. Thus, even in the Transit Model the particular orientation of the adjusted targets based on the P.P.D. Notes has an effect. Through period three, the pattern of new capital is affected by the initial endowments of capital-in-process and the optimizing mechanisms decisions as to the merits of completing these components. In the fourth and fifth periods, however, the optimizing mechanism has full choice, subject to terminal conditions, of course, as to the pattern of investment. The big increases in capacity in these periods in the major consumer goods producing sectors confirms the indications of the shadow prices that the system is concentrating on increasing output in these sectors.

Table 4-81 which indicates the proportions of idle capacity in each sector in each period shows a strikingly different pattern from the Target Model solutions. In this case the idle capacity is concentrated in the capital goods sectors and their major suppliers. The shift in emphasis

in the targets has created a whole new pattern of relative scarcities. With this new emphasis the idle capacities are so great in Equipment, Chemical, and Cement, Glass and Wood, and Electricity and Transportation sectors as to prevail throughout the plan periods. This difference in relative scarcities is also apparent in the shadow rentals on capital services and the shadow prices of capital in Tables 4-82 and 4-83 in which the highest values are now in the consumer goods sectors rather than in the capital goods sectors as in the Target Model.

The uses of foreign exchange for imports and the shadow prices on the competitive import ceilings in Tables 4-84, 4-85 and 4-86 also reflect the new emphasis. All of these relatively small shadow prices including those on the foreign exchange balance indicate that in this solution there are fewer major bottlenecks to increasing the value of the maximand since the open-ended system has a greater freedom to adjust to the constraints including the one on uses of imports. Because the GNP in the last year is lower in the Transit Model case, the non-competitive import requirements are not an absolute limit to total output in the last period as they are in the Target Model case.

The national income accounts in Table 4-87 indicate an uneven rate of growth of gross national product as well as consumption. The gross savings rates rise from 12.1% in the first period to 17.1% in the third period and then fall to 9.7% in the last period. This is an indication that the post-terminal conditions imposed in the Reference Solution by stipulation of growth rates which guarantee a less than 5% rate of increase in GNP are relatively easy to achieve. The total investment requirements of the Transit Model Reference Solution are shown in Table 4-88. The net

investment requirements are substantially less than the Rs. crores estimated in the Fourth Plan Target Model Reference Solution.

Turning back to the alternative solutions for the Fourth Plan Transit Model as summarized in Table 4-76, changes in the social discount rate have only a small effect as do changes in the consumption growth restraints.[1] A 10% increase in the initial endowments has a significant effect as would be expected but not as large as in the corresponding Target Solution case as the Transit Model is less subject due to its open-ended character to the bottlenecks which the Plan Targets create and which the change in initial endowments break.

Reducing the required post-terminal growth rate for consumption to 2.5% from 5% in solution R-8 brings only a small change in the value of consumption goods produced and leaves more slack in the system. Increasing the required post-terminal growth rate to 7.5% in R-9 reduces the amount of undiscounted consumption available in the plan period by about Rs. 2,500 crores. However the total capital stock on hand at the end of the plan period goes up by only Rs. 500 crores as compared to the Reference Solution since the level of consumption in the fifth year is lower in this case.

Since the import ceiling constraints and the foreign exchange constraints are not major bottlenecks, as indicated by the shadow prices, their relaxation does not lead to substantial changes in the character of the solutions as compared to the effects of such changes in the Target Model

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1 For this set of solutions the minimum intra-plan annual consumption growth rate was set at 5.0%. This qualifies only slightly, however, the comparisons which are made.

solutions. This is seen in solutions R-10 through R-18 in Table 4-76. Removal of the competitive import ceilings gives the model some added flexibility and the allocation of imports is now concentrated in one or two of the major consumer goods sectors in each period. The effect on the maximand is relatively minor but noticeable as is also the effect on savings and investment.

Increasing the foreign capital available increases the maximand but the effect is much smaller in the Transit Model solution than in the corresponding Target Model Solution F-1.2 in which foreign exchange availability constitutes a ceiling to output in the last period. The additional foreign capital substitutes for domestic savings in this case and the domestic savings rate falls by 0.5% to 1% in each period in the case of solution R-11 with 25% additional foreign capital. With still more foreign capital the domestic savings rate falls further.

Reducing the foreign capital inflow forces a reduction in the consumption which is made available and the output levels achieved. By the fifth period with 25% less foreign capital in solution R-14, gross national product is about 2.5% below that of the Reference Solution. The elimination of foreign capital reduces the consumption available by about 3%; the level of gross national product in the final plan year falls by 2%. The ability of the Transit Model solutions to adjust to reductions in foreign capital inflows is striking and naturally raises some questions when compared to the reality of foreign exchange stringency in India. The Transit Model solutions, of course, do not represent reality but an alternative set of targets so correspondence with actual events cannot be expected. Still the question remains of how the Transit Model achieves its relative

independence of foreign capital inflows. The answer is in the different patterns of outputs and targets of the Indian Plans and the Transit Model. The analysis suggests that the immediate effect of the attempt to create import substituting industries reflected in the Plan Targets is the source of foreign exchange stringency. The analysis is deficient, however, in that it does not indicate the subsequent effect of successful import substitution programs.

In solutions R-16 and R-17 the intra-plan export growth rate is changed, up and down, by 1%. The effects are relatively small as could be expected. A smaller amount of exports increases the availability of resources for domestic use and vice-versa.

In solution R-18 net foreign capital inflows are increased by 100% and the competitive import ceilings are removed. In these conditions, the additional foreign exchange is much more productive than when the ceilings are maintained.

Lowering the capital-output ratios in Agriculture and Housing has a smaller effect in the Transit as compared to the corresponding Target Model solution because of the greater stringency of capital in the latter case. But even in the Transit Model an unfavorable combination of specifications as in solution R-21 can lead to a drastic reduction in available consumption.

4.6 Evaluation of the Transit Model Solutions

As a guide to making policy the Transit Model suffers especially from its short run character which allows the model only limited opportunity to exercise discretion in determining the inter-temporal pattern of

consumption and investment and therefore the relative weights to be placed on the consumer and capital goods sectors. The overlapping constraints of the initial endowments and terminal conditions further restrict the freedom of the optimizing mechanism.

The Transit Models do provide additional understanding of the operation of the Indian economy and the Target Model solutions. They indicate the effects of the forces acting on the economy which arise from the expansion of consumer demands within the framework of domestic capital resources and foreign exchange resources without a long range vision of future goals. There appears to be a closer correspondence between the savings rates which have actually been achieved in the Indian economy and those of the Transit Model solutions than the Target Models. On the other hand the Transit Model solutions are not good descriptions of what has happened in India nor necessarily what will happen because their targets are so much different than those of the Plans. By comparison with Target Model solutions Transit Model solutions indicate the direction of the adjustment of the economy if inadequate saving and investment forced scaling down of the Plan targets and adjustment of their composition.

CHAPTER 5

THE GUIDEPATH AND THE GUIDEPOST MODELS

The fool who does not know
His own resource, his foe,
His duty, time and place,
Who sets a reckless pace,
Will by the wayside fall,
Will reap no fruit at all.

--The Panchatantra

5.1 Introduction

Policy making requires techniques for formulating as well as testing economic goals. The Target Model which can be used to analyze the short run implications of a given set of targets cannot deal adequately with the question of why the targets themselves are desired because the implications of a set of five year plan targets transcend the plan period itself. For the same reason the Transit Model, which contains an endogenous method for setting its own targets, cannot analyze the full implications of the targets. Planning involves decisions about the distant as well as the near future and concentration on short period planning inevitably omits relevant considerations. In principle the planning horizon should be infinite but in practice it must be truncated. Economic decisions are made in a more and more satisfactory manner as the time horizon is pushed out further and further until there are no further advantages to be gained vis-a-vis the immediate economic issues from exercising foresight.

A long term model for making economic policy would always be preferable to a short term model if the uncertainties associated with technical and behavioral coefficients did not increase with time for coefficients further in the future. If such increasing uncertainties are not accounted for in the optimization procedure it is conceivable that a shorter plan might turn out to be better than a longer plan. The optimum horizon cannot be known *à priori*, but in development planning it seems certainly to be more than the conventional five years. The short term models were presented first in the chapters above because of interest in their use in analyzing the Five Year Plan targets and other aspects of Indian economic policy. The basic justification for short term planning

models is their computational convenience, however, as the cost of calculations rises rapidly as systems are expanded to cover more and more time periods.

Because of their greater computational costs further compromises are made in the structure of the long term planning models in order to actually solve them. The type of compromise most frequently made has been the aggregation of the economy portrayed to one or two sectors. This has characterized many of the theoretical models which have been developed to provide more qualitative insights into the growth process. But aggregation imposes the assumption of full substitutability among all the commodities drawn into each sector. While not a disadvantage with respect to some issues, that assumption is a handicap to understanding when outputs and inputs are to an important extent specific in their uses. On the other hand, if, because of the absence of any other basis for decision, proportions among the outputs and inputs of different sectors are held constant, the sectors can just as well be aggregated and no knowledge ~~is~~ added by carrying them along separately. However, the various sectors contribute to the production of consumption and investment goods in different proportions. In turn, changes in the relative proportions of these goods over time mean changes in the relative weight of these sectors in the whole economy. A priori

it cannot be known whether aggregation of sectors, on balance, overstates or understates the potential achievements of a system. While aggregation permits full substitution within sectors, if the average input requirements it imposes on a particularly fast growing part of the economy are higher than if that sector were treated separately, the effect is to penalize growth.

Another device often used in growth models is the aggregation of time periods as this provides another means of reducing the computational burden of models with long time horizons. When discrete time periods are used in planning their length should be chosen so that the time shape of events within the period has no effect on the outcome. In many of the economically more advanced countries a year may be too long for this to hold true but it is still used in large part because it coincides with the conventional accounting period. In India the relative importance of the agricultural sector may provide more justification for annual accounting.

The aggregation of time periods has effects analogous to those of the aggregation of sectors; it implies complete substitution within the period. This provides an additional degree of freedom in breaking bottlenecks which is not in fact present and which is particularly significant for countries like India which are starting their development with an industrial composition substantially different from that toward which they are aiming. On the other hand, there may be compensating disadvantages since it forces a kind of synchronization among sectors in each aggregated time period which in actuality need not be present.

While the computational burden associated with long term models requires simplification of structure, it is also true that some elaboration

is desirable if the models are to provide guidance for short term planning. Long term plans can provide terminal conditions for short term plans and should also provide guidance as to the average values to be assigned to certain parameters. For short term plans it can often be assumed, for example, that consumption or input proportions will not change substantially within the plan period. However, even in five year plans it may be important to use different parameters in reflecting post-terminal conditions into the planning period. Furthermore, where a prediction can be made of a change in technology as, for example, in the foreseen displacement of a traditional with a modern technology, a long term model ought to provide a basis for determining the values of the technical parameters to be used in a short term model.

It is not possible to predict on the basis of qualitative arguments the quantitative effects of the various types of compromises in model structure as they will depend to a considerable degree on the particular economy being studied and the parameter values used. In the practice of economic policy making there should be a systematic exploration of alternative formulations. However, since our purpose, especially in conjunction with the long term models, is to develop techniques of planning we shall not be exhaustive in our own calculations. No twenty to thirty year detailed programs are publicly available for India which we can subject to the same type of testing which we performed on the Third and Fourth Five Year Plans. We can and will, however, indicate some of the alternative long run development policies which appear to exist and their implications. We shall also demonstrate a technique for linking an explicit long term plan to a short term, five year plan.

5.2 Structure of the Guidepath Model

The long-term model which we call the Guidepath Model is created by modifications and additions to the structure of the Basic Model core. The entire model will be described in this chapter, however, as some definitions will be modified and variables and relationships added. The description will be brief except where there have been significant modifications. The major structural changes in the long term as compared to the short term models are: (i) a greater degree of aggregation over time, (ii) the provision for endogenous change in consumption proportions through the use of expenditure elasticities, and (iii) the inclusion of a mechanism for an endogenously determined shift from a "traditional" to a "modern" technology in the agricultural sector. Inasmuch as the savings rate is of major importance in determining the character of the solutions the long-term model will be solved in two versions, the Guidepath I and Guidepath II formulations, which are distinguished by the explicit specification of a savings constraint in the latter case.

Table 5-1 lists the additional parameters and changes in definitions of variables for the Guidepath Models and Table 5-2 presents the complete set of relationships.

First of all, the time period is changed from one year to three years partly on the rationalization that events within such a relatively short period are unimportant for long term planning of fifteen to thirty years. This rationalization has more justification for the later years of a long term plan than for the early years in which imbalances and bottlenecks of various types may be of considerable importance. One way of dealing with this situation would be to change the length of the unit time

Table 5-1

List of Additional Variables and Parameters for Guidepath Model

$X_1(t)$ -- output of the "incremental" agriculture activity in period t

$X_{12}(t)$ -- output of the "traditional" agriculture activity in period t

η -- diagonal matrix of expenditure elasticities of consumption of each sector's output

$\lambda(t)$ -- population growth rate between periods t and t-1

τ -- growth rate of cultivable land available to agriculture

y_1, y_{12} -- yields of output per unit of land in "incremental" and "traditional" agriculture

$P(t)$ -- population in period (t)

U -- activity aggregation matrix

Table 5-2

The Guidepath-I and Guidepath-II Models

(1) Objective function

(1.0) Maximize: $W = \sum_{t=1}^{T} \frac{C(t)}{(1+w)^{t-1}}$

Subject to:

(2) Consumption growth constraints

(2.0) $C(t+1) \geq (1+\rho(t))C(t)$, for $t=0, \ldots, T-1$,

(2.1) Initial consumption

$C(0) = \overline{C(0)}$,

(3) Distribution relations

(3.0) $J(t)+H(t)+N(t)+Q(t)+F(t)+G(t)+E(t) \leq M(t)+UX(t)$, for $t=1, \ldots, T$,

$$\text{where } U = \begin{bmatrix} 1 & 0 & . & 0 & 1 \\ 0 & 1 & . & . & 0 \\ . & . & . & . & . \\ 0 & . & . & 1 & 0 \end{bmatrix}$$

(3.1) Intermediate products

$J(t) = a(t)X(t)$, for $t=1, \ldots, T$,

(3.2) Inventory requirements

(3.20) $H(t) = s(t)\ \{X(t+1)-X(t)\}$, for $t=2, \ldots, T$,

(3.21) $H(1) = s(1)\ \{X(2)-(1+c_0)\overline{X(0)}\}$, for $t=1$,

(3.3) Private consumption

$F(t) = \eta c C(t) + \left\{ \prod_{t=1}^{t} [1+\lambda(t)] \right\} (I-\eta) c\overline{C(0)}$, for $t=1, \ldots, T$,

(3.4) Government consumption

$G(t) = \overline{G(t)}$, for $t=1, \ldots, T$,

(3.5) Exports

$E(t) = \overline{E(t)}$, for $t=1, \ldots, T$,

Table 5-2 (continued)

(4) Capacity restraints

(4.0) $b(t)X(t) \leq K(t)$, for $t=1, \ldots, T$,

(5) Capital accounting relationships

(5.0) Investment requirements

$N(t) = pZ(t+1)$, for $t=1, \ldots, T$,

(5.1) Depreciated capital

$D(t) = \overline{D(t)}$, for $t=2, \ldots, T+1$,

(5.2) Depreciated capacity

$V(t) = dD(t)$, for $t=2, \ldots, T+1$,

(5.3) Restoration requirements

$Q(t) = r(t)d(t)^{-1}R(t)$, for $t=1, \ldots, T$,

(5.4) Capital accounting

$K(t+1) \leq K(t) + Z(t+1) + R(t+1) - V(t+1)$, for $t=1, \ldots, T$,

(6) Restoration ceilings

(6.0) $R(t) \leq V(t)$, for $t=2, \ldots, T+1$,

(7) Balance of payments constraints

(7.0) $\mathcal{U}M(t) \leq \overline{A(t)} + \mathcal{U}E(t)$, for $t=1, \ldots, T$,

(8) Imports

(8.0) Import composition

$M(t) = M'(t) + M''(t)$, for $t=1, \ldots, T$,

(8.1) Non-competitive imports

$M'(t) = m'(t)X(t)$, for $t=1, \ldots, T$,

(8.2) Competitive import ceilings

$M''(t) \leq m''(t)[\overline{A(t)} + \mathcal{U}E(t) - \mathcal{U}M'(t)]$, for $t=1, \ldots, T$,

Table 5-2 (continued)

(9) Relations between incremental and traditional agriculture activities

(9.0) $X_{12}(t) - [1 + \tau]X_{12}(t-1) \leq 0$, for t=1, ..., T,

(9.1) $X_1(t) - [y_M/y_{12} - 1]X_{12}(t) \leq 0$, for t=1, ..., T,

(10) Initial capital restraints

(10.0) $K(1) = b(1)(1+\alpha)\overline{X(0)}$,

(11) Terminal requirements in general

(11.01) $K(T+1) \geq \overline{K(T+1)}$

(12) Derivation of terminal conditions from post-terminal growth requirements:

Post-terminal growth rates of demands and imports,

(12.01) $C(t) = C(T)(1+\emptyset)^{t-T}$

(12.02) $G(t) = \overline{G(T)}(1+\gamma)^{t-T}$

(12.03) $E(t) = \overline{E(T)}(1+\epsilon)^{t-T}$

(12.04) $D(t) = \overline{D(T)}(1+\delta)^{t-T}$

(12.05) $M(t) = \overline{M(T)}(1+\mu)^{t-T}$

(12.06) $X_{12}(t) = \overline{X_{12}(T)}(1+\tau)^{t-T}$

(12.07) $F(t) = \eta cC(T)(1+\emptyset)^{t-T} + \left\{\prod_{t=1}^{t}[1+\lambda(t)]\right\}(I-\eta)c\overline{C(0)}$

which implies

$$
\begin{aligned}
(12.1)\quad \overset{*}{X}(t)+X_{12}(t) = {} & \overset{*}{a}(T)\overset{*}{X}(t)+[\overset{*}{s}(T)+\overset{*}{b}(T)\overset{*}{p}]\{\overset{*}{X}(t+1)-\overset{*}{X}(t)\} \\
& + [a_{12}(T)+(s_{12}(T)+b_{12}(T)p_{12})\tau]\overline{X_{12}(T)}(1+\tau)^{t-T} \\
& + \eta cC(T)(1+\emptyset)^{t-T}+\left\{\prod_{t=1}^{T}(1+\lambda(t))\right\}(I-\eta)c\overline{C(0)}(1+\lambda(T))^{t-T} \\
& + \overline{G(T)}(1+\gamma)^{t-T}+\overline{E(T)}(1+\epsilon)^{t-T}+\overline{D(T)}(1+\delta)^{t-T} \\
& - M''(T)(1+\mu)^{t-T}-\overset{*}{m}'(T)\overset{*}{X}(T)(1+\mu)^{t-T}-m'_{12}(T)\overline{X_{12}(T)}(1+\mu)^{t-T},
\end{aligned}
$$

for $t > T$.

Table 5-2 (continued)

Define $q_\xi \equiv [I-\overset{*}{a}(T) - (\overset{*}{b}(T)p + \overset{*}{s}(T))\xi]$, for $\xi = \tau, \lambda(T), \emptyset, \gamma, \epsilon, \delta, \mu$.

Then, particular solution of (12.1) for t=T+1:

$$
\begin{aligned}
(13.0)\quad \overset{*}{X}(T+1) = {} & [\overset{*}{q}_\tau]^{-1}\,[-I+a_{12}(T)+(s_{12}(T)+b_{12}(T)p_{12})\tau]\overline{X_{12}(T)}(1+\tau) \\
& + [\overset{*}{q}_\emptyset]^{-1}\eta c C(T)(1+\emptyset) \\
& + [\overset{*}{q}_{\lambda(T)}]^{-1}\left\{\prod_{t=1}^{T}(1+\lambda(t))\right\}(I-\eta)c\overline{C(0)}(1+\lambda(T)) \\
& + [\overset{*}{q}_\gamma]^{-1}\overline{G(T)}(1+\gamma) \\
& + [\overset{*}{q}_\epsilon]^{-1}\overline{E(T)}(1+\epsilon) \\
& + [\overset{*}{q}_\delta]^{-1}\overline{D(T)}(1+\delta) \\
& - [\overset{*}{q}_\mu]^{-1}M''(T)(1+\mu) \\
& - [\overset{*}{q}_\mu]^{-1}m'(T)\overset{*}{X}(T)(1+\mu) \\
& - [\overset{*}{q}_\mu]^{-1}m'_{12}(T)\overline{X_{12}(T)}(1+\mu) ,
\end{aligned}
$$

Then from (13.0) ,

Terminal capital stocks:

$$
\begin{aligned}
(14.0)\quad & \overset{*}{K}(T+1) \geq \overset{*}{b}(T)\overset{*}{X}(T+1) \\
& K_{12}(T+1) \geq b_{12}(T)\overline{X_{12}(T+1)}
\end{aligned}
$$

Terminal inventories

$$(14.1)\quad s(T)X(T+1) \geq \overset{*}{s}(T)\overset{*}{X}(T+1)+s_{12}(T)\overline{X_{12}(T+1)}$$

(15) Consumption or savings constraint for the Guidepath-II Model

$$(15.1)\quad C(t)+uG(T) \geq \beta_0 + \beta u[(I-A)X(t)-\overline{D}(t)] , \qquad \text{for } t=1, \ldots, T .$$

period over the planning horizon. This approach has some complexities in programming which we avoid by making detailed short term plans using the long term plans as a guide. The three year period is chosen in order to collapse the gestation lag. Most of the relationships will not have to change as a result of this modification but the magnitude of those parameters which have time dimensions will have to change. The capital-output ratios, for example, which have a time dimension, will be divided by three. Extending the unit period may have a retarding effect on growth as it effectively lengthens the gestation lag in some sectors. Offsetting this is the assumption that resources and production in any one of the three years of the unit period are perfectly substitutable. The maximand (1.0) is the same as in the Basic Model but the unit period is now three years so C(t) is the sum of private consumption in three years. w is the discounting factor applied to C(t) and is similarly adjusted so that it reflects the three year period. Provision is again made in (2.0) for a growth constraint on total consumption.

Since in this model there are two activities producing agricultural goods the accounting must be adjusted to reflect this. Both activities deliver agricultural output to fulfill the various requirements for it. The total agricultural output is obtained by summing the outputs of both the activities. This is indicated by use of the activity aggregation matrix [U] in the distribution equation (3.0). The matrix [U] is a rectangular matrix with rows equal to the number of sectors and columns equal to the number of activities. Element $U_{ij} = 1.0$ if the jth activity contributes to the ith sector; otherwise $U_{ij} = 0$. We find it convenient to make the first activity "incremental" agriculture and the twelfth

activity "traditional" agriculture. Then the [U] matrix is as shown below

$$U_{11x12} = \begin{bmatrix} 1 & 0 & \cdot & \cdot & \cdot & 1 \\ 0 & 1 & & & & 0 \\ \cdot & & \cdot & & & \cdot \\ \cdot & & & \cdot & & \cdot \\ \cdot & & & & \cdot & \cdot \\ 0 & 0 & \cdot & \cdot & 1 & 0 \end{bmatrix}$$

Each of the activities in Agriculture has a different technical coefficient and the matrices a(t) of intermediate inputs, s(t) of inventory output coefficients and p the capital proportion matrix are all, therefore, rectangular. The intermediate requirements for output are shown in (3.1). The relationships for inventory requirements (3.20) and (3.21) are like the analogous relations in the Basic Model.

In the Guidepath Models the proportions in which each sector contributes to aggregate private consumption are no longer specified exogenously but are determined by consumption-expenditure elasticities, η_i, and initial proportions. The expenditure elasticity η_i for sector i is defined as follows:

$$\eta_i = \frac{F_i(t)/P(t) - \overline{F_i(0)}/\overline{P(0)}}{\overline{F_i(0)}/\overline{P(0)}} \Bigg/ \frac{F(t)/P(t) - \overline{F(0)}/\overline{P(0)}}{\overline{F(0)}/\overline{P(0)}}$$

where P(t) is the population in period t. P(t) is obtained from the initial population P(0) and the projected growth rates of population $\lambda(t)$ as

$$P(t) = P(0)[1 + \lambda(1)][1 + \lambda(2)] \ldots [1 + \lambda(t)] = P(0) \prod_{t=1}^{t} [1 + \lambda(t)]$$

With $\overline{F(0)} = c\overline{C(0)}$, where c is the vector of initial consumption proportions, the sectoral private consumptions in period t can be written as in (3.3)

$$(3.3) \qquad F(t) = \eta c C(t) + \left\{ \prod_{t+1}^{t} [1 + \lambda(t)] \right\} (I - \eta) c\overline{C(0)}$$

With this formulation the proportions of sectoral to aggregate consumption will vary with the growth of total consumption. However, it should be realized that this still does not provide freedom to substitute one good for the other in consumption in any period.

The demands for government consumption and exports, (3.4) and (3.5), are exogenously determined. The form of the capital accounting relationships (5) does not change except that, with the aggregation of the time period there is only a one period gestation lag. Consequently there is only one p matrix and one r matrix.

Depreciation and replacement is treated exogenously as in the short run model. When the planning period exceeds the lifetime of the shortest lived component of capital, the model should have some provision for recording for depreciation purposes amounts invested during the plan period. This procedure was not followed since it would require substantial additional accounting and the long term model's computation requirements were already heavy. In the present case the length of the planning period is only slightly longer than the life of the shortest-lived component so the exogenous specification of depreciation for the entire plan period is kept. This requires a guess about the rate of investment in the various sectors during the early part of the plan period.

The gross investments made since the beginning of the First Plan in 1951 are substantially different in composition from the assumed steady

state prior to 1951. These investments come up for replacement during the long term plan period. Consequently the replacement proportion matrix r(t) and the depreciated capacity transformation matrix d(t) are different in each period and so they now have time subscripts in equation (5.3).

The balance of payments constraints remain unchanged and imports in any period may not exceed the available foreign exchange in that period. Although there is no provision endogenous to the model for changing the proportion of non-competitive imports to output, this is done exogenously by changing specification of the m' coefficients. The model is run without limitations on the degree of specialization of competitive imports by setting all the m" coefficients equal to one in (8.2). This type of specialization could be allowed to occur only slowly and the m" coefficients changed at a moderate rate.

The Guidepath Models also provide for a shift from traditional to modern technology in the agricultural sector. This sector is by far the largest in the Indian economy and provides the largest component of the consumer's budget. Intensive efforts are underway to change its technology and while in the short run these may have only a marginal effect, in the long run they must be successful if India is to maintain a viable economy. Satisfactory treatment of the requirements for agricultural expansion are particularly crucial, therefore, in projecting long-run development in India. Agricultural development is a complex of social reorganization, additional inputs and technological change. If it is successful more capital inputs and more of some, though less of other, current inputs will be required. The consequence will be an increase in land and labor productivity. If the model were allowed to choose between alternative

traditional and modern input vectors and capital coefficients it might well choose the former. This would happen if the inputs into the traditional technology are less costly in terms of the scarce factors which appear in the model than the inputs required by the modern technology. However, by imposing a limit on the output of the traditional sector the model can be forced to shift to the modern technology in order to satisfy the increasing demands on the sector. The model must be provided with the current input vectors for the alternative technologies and the capital coefficients and the two productivities of land must be specified. In addition a constraint must be added embodying the limits on output imposed by the available land when used with the two technologies.

The inequalities of (9.0) and (9.1) are required because of the new treatment of the agricultural sector.

When the terminal levels of capital stocks are endogenously determined it becomes necessary to specify the level of output in one of the two activities producing agriculture. In order to do this it is convenient to consider the agricultural sector as composed of "traditional" and "incremental" activities rather than "traditional" and "modern" activities. The process of modernization is viewed not as one in which the modern sector displaces the traditional sector on existing land. Rather it is as if incremental inputs to supplement the traditional inputs are applied to the same piece of land. The land then yields both traditional and incremental outputs.[1] In this formulation the traditional

1 The 'incremental' sector can be conceived of as the additional output that the Village Level Extension Worker gets by applying additional inputs from the same piece of land on which the farmer has applied the traditional inputs to get his traditional output.

sector may continue to operate throughout the planning period on all the land that is cultivable. The available cultivable land is assumed to increase by 0.5 per cent a year due to reclamation efforts. The maximum available cultivable land for each period is thus known and during the planning period the traditional activity is limited by this ceiling in each period. Restraints (9.0) reflect these ceilings. The incremental agriculture activity cannot be operated on any land that is not cultivated by the traditional activity. Thus the 'incremental' activity in each period is confined to the land actually cultivated by the traditional activity in that period. The constraints (9.1) stipulate this requirement. An explicit specification of these constraints is necessary because the "incremental" inputs without the necessary traditional inputs which they supplement may be less costly than the traditional agricultural inputs.

For the post-terminal years it is assumed that traditional agriculture uses all the cultivable land that is available and thus the terminal level of output of traditional agricultural activity is fixed. It may happen that the model solution indicates idle land capacity in the terminal year in which case the assumption of full use of land in post-terminal years would not be optimal. An iterative procedure would then be required to stipulate the terminal level of traditional agriculture. However in the solutions presented below this was not necessary. The input coefficients for the newly defined traditional sector are the same as those for the traditional sector conventionally defined. The input coefficients in the incremental agriculture sector are derived as follows. Consider a unit of land in modern agriculture. The vector of inputs applied to the

land is $a_M y_M$ where a_M is the vector of input coefficients for the modern agriculture, and it produces output y_M. Alternatively, if the unit of land were viewed as employed in incremental and traditional agriculture, their inputs, $a_1 y_1 + a_{12} y_{12}$, would produce the same output; i.e., $y_1 + y_{12} = y_M$. Total inputs must be the same in either interpretation, so,

$$a_1 y_1 + a_{12} y_{12} = a_M y_M$$

i.e.

$$a_1 = \frac{a_M y_M - a_{12} y_{12}}{y_M - y_{12}} = \frac{a_M y_M - a_T y_T}{y_M - y_T}$$

The capital coefficient b_1 is similarly derived, and

$$b_1 = \frac{b_M y_M - b_T y_T}{y_M - y_T}$$

Since the time aggregation has reduced the investment lag to one period there is no initial capital in process, and only the initial capital capacities need be specified in order to start the model solution. This is shown in (10).

The technique for a partly endogenous determination of terminal conditions which is used in the Transit Model is used in the Guidepost Model also.

In equations (12.0) not only the post-terminal growth rates for demands and imports but also the level and the growth rate of the output of the Traditional Agriculture activity are specified. In the distribution

equations (12.1) for the post-terminal years, $\overset{*}{a}(T)$, $\overset{*}{s}(T)$, $\overset{*}{b}(T)$, $\overset{*}{p}(T)$ and $\overset{*}{m}'(T)$ are the square matrices for the first eleven activities. The twelfth columns for the Traditional Agriculture activity have been separated from each of these matrices and are denoted by $a_{12}(T)$, $s_{12}(T)$, $b_{12}(T)$, $p_{12}(T)$ and $m'_{12}(T)$. Similarly $X(t)$ is partitioned into $\overset{*}{X}(t)$ and $X_{12}(t)$. For the post-terminal period in (12.1) all the coefficients are assumed to remain constant at their terminal period values.

The particular solution (13.1) gives the output levels of the first eleven activities for the post-terminal period from which the terminal capital and inventory stocks are derived in relations (14).

Relationships (1) through (14) complete the description of the Guidepath-I Model.

The Guidepath-II Model embodies an additional constraint in the form of a behavioral relation of private and public consumption to national income. This is shown in (15.0).

$$(15.0) \qquad C(t) + \mathcal{U}G(t) \geq \beta_0 + \beta_1 \mathcal{U}[(I-A)X(t)-\overline{D}(t)], \qquad \text{for } t=1, \ldots, T .$$

The additional constraints (15.0) constitute limits on the maximum net savings rates that can be realized in each period. This reflects an institutional limitation on the ability to raise savings. The coefficient β_1 in (15.0), which is the marginal propensity to consume, may be altered by economic policy and can be considered a policy parameter. Without this constraint the model is similar to the theoretical models designed to find an "optimal savings program" limited on the consumption side only by the floors which are set for consumption. As pointed out previously specification of these minimum levels would not be required if there were reason to believe

that the objective function was a good representation of the social welfare function. Since this is not the case, and there is no way of knowing that social welfare function directly, its role in the model is simulated by various types of constraints of which (15.0) is one.

5.3 The Guidepost Models

These models are really versions of the Target Model. They are given a new name since their terminal conditions are based on solutions to the long term Guidepath Model and since the structural changes of the Guidepath Models are retained even though the Guidepost Models are short run models. Compared to the Target and Transit Model solutions the Guidepost solutions are compatible with an explicit long term optimizing path. They provide a more detailed working out of the first years of the Guidepath solution.

In this case the procedure for establishing terminal conditions is based on the third three year period stocks of the Guidepath Model's solution. These are interpolated to determine conditions for the Guidepost Model which provide the same capital stocks in the post-terminal years as provided by the Guidepath solution for the same years.

5.4 Character of the Guidepath Model Solutions

The Guidepath Models may be regarded as multi-sectoral versions of finite horizon, linear models of capital accumulation and growth with the addition of a number of exogenously specified demands on the system. As such the general quality of the solutions may be predicted from the simpler models which have already been worked out in a number of variations. Depending on the rate at which consumption is discounted and on the productivity of investment, there will be a tendency to concentrate consumption at the beginning or end of the planning period. This so-called "flip-flop" or "bang-bang" tendency which is quite marked in the simpler, linear models will be moderated in the Guidepath solutions by a number of features of the Models. First of all, there are many sectors, each with different initial capacities, input requirements and demands for consumption and investment. These create effective, overall non-linearities in the model even though the relationships in each sector are linear. The provision of two activities in Agriculture with different input requirements makes the aggregate output of that sector respond in a non-linear fashion to total inputs to the sector. The composition of consumption demand, of export demand and of depreciation change over time as do import and inventory coefficients and the availability of net foreign capital inflows. Unlike single sector models in which capital can be consumed or used for further production, the capital stocks in the Guidepath Models are durable and cannot be eaten up all at once even if that were to be desired. In addition the terminal conditions which guarantee post-terminal growth from the endogenously determined consumption levels of the final plan period tend to depress the level of consumption in the final plan period.

All of these elements act to create a feasibility hypersurface which is multi-faceted. An increment in consumption gained in a future period is not linearly related to the current sacrifice in consumption necessary to gain the increment. As a result the solutions to the Guidepath Models cannot be expected to take on a simple flip-flop pattern though this remains an underlying tendency. Yet, though the non-linearities avoid the extremes of the flip-flop pattern they will not necessarily provide a desirable pattern of consumption. One of the objectives of the alternative solutions will be to find methods of achieving the patterns desired.

The long planning period and the reduction in intertemporal dependence which results from collapsing the gestation lag provides the Guidepath Models with more freedom to choose a time pattern of output than is available to the Target and Transit Models. Otherwise the discussion in Chapter 2 of the characteristics of the optimizing process and the role of the shadow prices applies here as well.

5.5 Additional Data and Assumptions for the Guidepath and Guidepost Models[1]

Long term planning calls for additional data which are intrinsically more difficult to provide than the data required for short term planning. Technological change can be expected to modify current and capital flow coefficients. Income elasticities will change with time and income. New products may be introduced. Yet there are no generally accepted techniques and empirical materials with which to predict such changes. In general parameters appropriate to different time periods could be embodied in the model, if they are known. The obstacles to better specification are as much empirical as theoretical. For example, although the method described

1 Numerical tables and figures for this chapter are presented separately in the accompanying volume.

above for agriculture to provide for a change in technology could be used in other sectors, the data available to us did not warrant it.

For the 1960-61 "a" matrix which has previously been used, another matrix was substituted for the period after 1971-72. This is based on a modification of the 1959-60 "a" matrix projected for 1970-71 by Rudra and Manne.[1] After some investigation of the possibility of substituting matrices for other countries for later periods the attempt was dropped. If it could have succeeded, it would have required far more time and resources than were available to us to establish comparability. The same conclusion was drawn after trying to find alternative estimates of capital coefficients. The input requirements for modern agriculture are, however, taken from the input vector of a Japanese input-output matrix.[2] The capital output ratio of 2.5 is used for modern agriculture in all but one solution in which a ratio of 4 is used. The composition of capital in it is obtained from Japanese data.

The inventory coefficients are reduced by 1.0 per cent every year, i.e. 3.03 per cent every 3 year period in the Guidepath Models to reflect a common conjecture as to their behavior.

The depreciation and replacement requirements for the longer period are estimated from the estimates of investments made during the First, Second and Third Plans. Likewise procedures similar to those previously employed were used to project the government and export vectors. In the

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1 A. Rudra and A. Manne, Studies in the Structure of the Indian Economy.

2 An unpublished paper by S. Ichimura and S. Miyano, "A Dynamic Input-Output Model of the Japanese Economy."

former case the sectoral composition of government demand is held constant and the total is projected at the rate of 6.0 per cent per annum, i.e. 19.10 per cent per period. Exports of each sector are projected at different rates representing a judgment as to the sector's potential. The numbers used could only be called guesses based on judgment of recent years' achievements and on the projections of potential shares of total markets made by B. Balassa.[1]

The "non-competitive" import coefficients are reduced from period to period to reflect growing self-reliance. No restraints on the use of foreign-exchange for competitive imports are introduced in the Guidepath and Guidepost Models.

Estimates of expenditure elasticities are required for the models. There is an abundance of data for India stemming mainly from the National Sample Surveys conducted by the Indian Statistical Institute though extensive analysis of these data has not yet been fully successful in establishing comparability. Moreover, the goods categories for which the elasticities have been estimated do not in general conform to the sectoral classifications of the input-output tables.

New research on this subject was beyond the scope of the project so the estimates used in the computations reported here are no more than personal judgments based on existing analyses of Indian data and international comparisons.[2] There is clearly material and scope for further

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1 B. Balassa, Trade Prospects for Developing Countries, 1964.

2 For purposes of comparison we used the study by H. Houthakker, "An International Comparison of Household Expenditure Patterns, Commemorating the Centenary of Engel's Law," Econometrica, Vol. 25, Oct., 1957, pp. 532-551.

analysis which would reorganize and re-estimate consumption-expenditure relationships in categories more useful for policy purposes.

The ratio of consumption and NNP in the last year of the Third Plan as projected by the Perspective Planning Division is used along with alternative marginal savings rates to determine the parameters of the consumption-income constraint when it is enforced.

In most cases net foreign capital inflow is set at 500 crores per annum until 1977 after which it is set to zero. This reflects in a rough way a frequently stated Indian goal of self-sufficiency by the Fifth Plan. In alternative solutions this stipulation is changed and the net foreign inflow is increased or the period of availability extended.

The first solutions to the Guidepath-I Model cover a span of eighteen years in six periods each of three years duration. Although this is only one more period in length than the five year models, the time aggregation actually gives the model much more freedom with which to allocate resources. The initial and terminal conditions now affect only the initial and final periods rather than overlapping to constrain the entire path. A solution for thirty years in ten three year periods will also be presented. The data inputs are shown in Tables 5-3 through 5-13.

5.6 Solutions to the Guidepath-I Models

5.6.1 Overall Patterns

Each solution to the Guidepath Model illustrates an alternative potential path of development which corresponds to a particular specification of parameters. In order to find a most desirable or even an acceptable solution it is necessary to carry out a series of iterations. The iterative approach is required partly because of the linearities in the model and partly because of difficulties in specifying precisely all of its parameters. Out of the many possible solutions which have been found we shall present only a few in order to illustrate certain properties of the model and to demonstrate the significance of alternative time preferences and policies.

The process of finding "acceptable" solutions is illustrated in Table 5-14 and Figure 5-1 which plots the time paths of consumption generated in alternative solutions to the Guidepath-I Model for six three year periods. Case G-1 is a solution in which the only requirement on the consumption pattern in the intra-plan period is that aggregate consumption not fall from the level of the preceding period. Furthermore the discount rate w is set to zero in G-1. It can be seen that it behaves somewhat in the flip-flop manner, by holding consumption to a minimum in the early periods and then pushing it up very rapidly in the later periods. The period in which the big increase comes and the subsequent pattern of consumption production depends in part on the effective aggregate capital output ratio and in part on the post-terminal growth requirement which is imposed. The model chooses to keep consumption in the last period at the same level as in the fifth period in this

solution as a higher level would only increase the investment requirements for post-terminal growth. Since the effective, aggregate capital output ratio in the Guidepath solution with its three year periods is less than one the big jump in private consumption should occur in the last period. However the post-terminal capital requirements depend upon the level of private consumption in the terminal period. To satisfy these requirements at lowest cost to the maximand the model solution if not constrained would tend to depress that level until it does not have to provide any additional capital for the post-terminal periods. Hence the jump in consumption occurs in the fourth period rather than the sixth period in case G-1.

The post-terminal consumption stream can be introduced explicitly in the objective function by adding a second term in the maximand:

$$W = \sum_{t=1}^{T} \frac{C(t)}{(1+w)^t} + C(T) \sum_{t=T+1}^{\infty} \frac{(1+\phi)^{t-T}}{(1+w)^{t-T}}$$

This is used in solution G-2 in which a weight of 4.0 is given to the terminal period consumption. The objective function becomes

$$W = C(1) + \ldots + C(T)\left\{1+\left(\frac{1+\phi}{1+\sigma}\right)^{t-T} + \left(\frac{1+\phi}{1+\sigma}\right)^{t-T+1} \ldots\right\}, \text{ where } \phi = 0.4238,$$

the required post-terminal rate of growth of consumption and where σ, the discount rate for the post-terminal consumption, is 0.24/ per year. In G-2 a 26% higher level of consumption is reached in the sixth period than in solution G-1. More extreme "flip-flop" behavior in the form of still greater concentration of consumption in the last period is prevented by the lack of foreign exchange required for non-competitive imports. In

solution G-2 all of the available foreign exchange is used for non-competitive imports in all periods but the first. This happens in spite of the fact that the non-competitive import coefficients are reduced every two periods in order to reflect import substitution. The import requirements in the terminal period are 2.14% of the gross national product compared to 5.37% of the gross national product in the first period.

Social discount rates on consumption of 10% per year, 20% per year and 30% per year are applied successively in solutions G-3, G-4 and G-5 with post-terminal consumption growth requirements of 12.5% per year. The intra-plan consumption growth constraints are removed so not even monotonacity is required. Removal of this requirement permits the flip-flop tendency to show itself more clearly if it exists. It is most obvious in solution G-3 in which consumption declines absolutely in the third period in order to accumulate capital in the capital-producing sectors at a high rate. The pay-off to this accumulation comes in the fourth and fifth period. The model solution now reduces consumption in the last period to reduce the diversion of resources to post-terminal growth. The higher discount rates in solutions G-4 and G-5 offset the flip-flop shown in G-3 and lead to consumption patterns in which a much higher proportion of total consumption is provided in the first three periods. The effective non-linearities in the model prevent a full reversal of the pattern of consumption in solution G-3 and the pattern is one of smooth growth until the weight of the post-terminal conditions leads to a reduction of the consumption produced in the last plan period.

The concentration of consumption at the end, or at the beginning, of a planning period is a feature of linear models rather than an essential

economic property of growth. Not only does such behavior violate a general sense of what is considered an acceptable time shape of consumption but it forces drastic changes in resource allocations on the system in particular years. It may even be difficult to reproduce in practice the characteristics of the solution. In order for the Guidepath Models to be useful, therefore, it is necessary to find methods of altering the shape of the time path of aggregate consumption to conform, within the limits of economic feasibility, to the dictates of policy. The first device used is simply that of setting constraints on that path. In solution G-6 minimum growth constraints are imposed on consumption in successive periods of 5%, 6%, 7%, 8% and 9% per year, and a post-terminal growth requirement of 12.5% per year of consumption is required. This solution is also plotted in Figure 5-1. The effect of the progressively higher consumption growth requirements in raising the levels in the early years and smoothing the overall path is apparent. Solution G-7 in Figure 5-1 has consumption growth constraints in successive periods of 6%, 7%, 8%, 9% and 10% per year and post-terminal consumption growth requirement of 10% per year.

Table 5-14 and Figure 5-1 also illustrate the overall effects of adding constraints. The level of consumption reached in the final period by solution G-1, without intra-plan consumption growth constraints but with a 12.5% per year post-terminal growth requirement, is less than that in solutions G-6 and G-7 with the same post-terminal growth constraint but with intra-plan consumption growth requirements of 5% and higher. The value of the maximand in solution G-1 is higher, of course, as the intra-plan growth constraints force a higher level of consumption in the early

plan years at the sacrifice of aggregate consumption over the entire plan period.

In order to test further the significance for the results of changes in the length of the planning period a few trials were made with the Guidepath-I Model covering ten three-year periods, or thirty years.

Figure 5-2 presents the time path of consumption generated by solutions to the Guidepath-I Model for ten periods. In solution G-8 the intra-plan requirement on consumption is only that consumption in any period may not fall below the level attained in the preceding period, and the post-terminal requirement is that consumption be able to grow at 12.5 per cent per year. Again the solution exhibits the "flip-flop" tendency, delaying any increase in consumption until the latter portion of the planning period when it is pushed up very rapidly. Also, as in the analogous six period solution G-1, the post-terminal consumption growth requirement is responsible for the constancy of consumption in the last three periods since this pattern requires a smaller diversion of resources to meet the post-terminal requirements than one with higher terminal consumption levels. The effect of imposing intra-plan consumption growth requirements between successive periods of 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12% and 12.5% per year while keeping the 12.5% per year post-terminal consumption growth requirement is shown in Figure 5-2 as solution G-9. For purposes of comparison, the solution G-6, which has similar intra-plan consumption growth requirements for six periods is also plotted in Figure 5-2. The close correspondence of the overall results for the first four periods is quite evident. The national income accounts for solutions G-6 and G-9 are presented in Tables 5-15 and 5-16 respectively.

In these first four periods the consumption growth constraint is binding in both models. In both cases the solutions are just satisfying these constraints and otherwise saving and investing for the future. The differences in the fifth and sixth periods reflect the influences of terminal conditions. In the six period model the 12.5% post-terminal growth requirement is reflected into the sixth period and the model is beginning some part of its adjustment to these post-terminal requirements even in the fourth and fifth periods. However, in the ten period case the model is continuing its policy of delaying consumption until it is ready for the big change of the sixth period whereas in the six period case the biggest increase in consumption comes in the fifth period. As the overall results suggest, the sectoral uses and allocations of resources in the six and ten period models are quite similar in the first three periods and after that diverge in their relative emphasis on consumption and capital goods production. Thus the edge effects of terminating the Guidepath-I solutions presented extend up to two or three periods into the plan period. This knowledge provides a basis for choice of the length of the plan period for which extensive investigation of parametric variations should be carried out. However, it should be pointed out that with a different set of parameters the edge effects could extend all the way to the first period so these results should not be generalized.

In the national income accounts for solution G-9 in Table 5-16, it will be noticed there that in the ninth period there is substantial amount of disinvestment in inventories and that there is no fixed investment in the tenth period. This is the result of the ceiling on total output of Agriculture imposed by the full use of the limited amount of

land. Even when all the available land is modernized the maximum level of consumption in the tenth period is still restricted by the limited output of Agriculture.

Since investment goods production requires Agricultural output as an intermediate input, all investments for the terminal targets are made in the ninth period to maximize consumption in the tenth period. Consequently the output of investment goods sector is higher in the ninth period than in the tenth period. This leads to disinvestment in inventory in the ninth period.

5.6.2 Details of the Guidepath-I Solutions

Solutions G-10, G-11 and G-12 are computed with the data as given in the section 5-5. They differ from solutions G-1 through G-9 in initial capacities, non-competitive import coefficients and in the "a" matrix from third period onward, and the two sets are thus not strictly comparable.[1] Solution G-10, which has the same consumption growth requirements as solution G-6, is used as a Reference Solution. Tables 5-17 to 5-26 present various features of the Guidepath-I Reference Solution. The national income accounts are shown in Table 5-17. The overall rate of growth of gross national product ranges from 7.8% to 12.7%. This is mainly the result of the high rates of investment. Net foreign capital inflows contribute to this investment, of course, but domestic savings are by far and away the largest source. This is reflected in the high average

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1 In solutions G-10, G-11 and G-12 the initial capacities are based on the adjusted estimated outputs of 1965-66, so that these solutions may be compatible with the Fourth Plan period solutions of Chapter 4. Solutions G-1 through G-9 have small discrepancies which make them less comparable.

savings rates which are created by the even more unusually high marginal domestic savings rates as shown in Table 5-17. The savings rate information helps to dispel some of the possible wonder at the growth performance reflected in the solution. Not only is the model behaving optimally in allocating resources and directing production for current output but also it is plowing back its output into investment for further growth at increasingly high rates.

It should be noted that since labor and raw materials are assumed to be always in adequate supply in the model, no restraints on growth arising from their scarcity are created. To the extent that these assumptions are true at all, they are likely to be so only in the earlier part of the plan period.

The composition of output in the Reference Solution is shown in Table 5-18 in each period of time. It will be noticed that the solution reflects a growing "industrialization." Table 5-19 ranks the sectors in terms of the growth rates from the first to the post-terminal period. Mining and Metals, Electrical Generation and Chemicals have markedly the highest growth rates. Equipment, Cement-Glass-Wood, Transportation and Construction are in the next group with roughly similar growth rates. The last, slowest growing group includes the Other and Margin, Food and Clothing, Housing and Agricultural sectors. However, it will be noticed that the Incremental Agriculture activity continues to grow rapidly even after it has achieved a position dominating Traditional Agriculture by the fifth period or fifteenth year. The outputs for the seventh period are those required by the terminal conditions. The output of the Incremental Agriculture activity is slightly more than three times the output of the

Traditional Agricultural activity. This is inconsistent with the assumption of a productivity ratio of 3.0 between the two activities.[1] The lack of cultivable land will make the outputs of the seventh period unachievable unless technological progress has made modern agriculture more productive by then.

The shadow prices on output for each period are shown in Table 5-20. The tendency for the prices to fall over time is a result of the greater contribution to the maximand which is made by output in the early as compared to the later periods because the post-terminal consumption is not explicitly included in the objective function.

It will be recalled that in the Guidepath-I solutions presented the constraints on the use of foreign exchange for "competitive" imports were made inoperative. Table 5-21 shows non-competitive and competitive imports by sectors.[2] Table 5-21 also includes the shadow price on the foreign exchange balance constraint.

The existence of competitive imports in each period indicates that the availability of foreign exchange does not set an absolute limit to output. The usefulness of foreign exchange here is reflected in the shadow price on the balance of payments constraints. Without the constraints on competitive imports which were imposed in Target and Transit Models, the shadow prices on the foreign exchange balance reflect the

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1 This is possible in the post-terminal period in the model, since the inequalities (9.1) cannot be included in deriving (13.0) for post-terminal output.

2 Since competitive imports for the post-terminal period, M"(T+1), do not enter the model explicitly the linear programming solution does not prevent "competitive" imports from being negative though, of course, total imports in a sector must be non-negative.

value of the output of the sector in which competitive imports are made.

Table 5-22 presents the sectoral consumptions in each period. These now reflect the consumption-expenditure elasticities specified for each sector. Although Agriculture continues to provide the largest single component of consumption its share is reduced by 16% from 38% to 32% over the planning period. By comparison the share of Equipment in total consumption increases by 50% from 2.6% to 3.9%.

The shadow prices on the consumption growth constraints are also shown in Table 5-22. The relatively high prices in the initial period reflect the tendency of the model to concentrate consumption toward the end of the period. Between the fourth and fifth periods the model solution would anyway increase consumption so the constraint is not binding.

The available capital stocks and the new capital capacity becoming effective in each period are shown in Tables 5-23 and 5-24 and the shadow price of new capital in Table 5-25.[1] The rapid growth of the capital stocks is the result of the high rates of saving and investment. It might be noted that the pattern of accumulation varies considerably from period to period though the relative prices on new capital do not change substantially. The changes in the investment pattern can be associated with the consumption growth path. In the early periods when consumption grows relatively slowly, the emphasis is on investment in the capital goods producing sectors and their major suppliers. In the fifth period when consumption grows more rapidly, the emphasis switches to accumulation in the consumption producing sectors. The industrial sectors (Mining and Metals,

1 All the new capital available at the beginning of the first period is already included in the specified total initial endowment.

Equipment, Chemicals, Cement-Glass-Wood and Electricity) had 24.9 per cent of the capital at the outset, their total share by the third period rises to 35.6 per cent and the share in the sixth period is 37.4 per cent.

The use of the capital is indicated in Table 5-26 which shows the ratio of idle to total capacity. The substantial amounts of idle capacity in the first period reflects the lack of "balance" in the initial conditions as compared to the proportions in which this particular solution would like to have capacity available. The initial "imbalance" is eliminated in the second period.

In judging the significance of the pattern of accumulation and use of capital many of the qualifications applied to the Target and Transit models because of their short time horizon do not apply. The time period is sufficiently long that explanations based on events and goals of the post-planning period such as import substitution and self-sufficiency have less weight than in the shorter models to the extent that the longer term model adequately reflects such goals in its constraints and parameters.

In addition, while the treatment of changing technology in agriculture and the change in consumption proportions is still quite simple, the present models meet some of the possible objections to the rigid treatment of these aspects of planning in the Target and Transit Models. The Guidepath-I Model for six periods is solved with several variations in parameters. In Table 5-27 the period-by-period national income accounts are shown of solution G-10.1 with net foreign capital inflow doubled for the same twelve years in which it was available in the previous solutions. Comparison with Table 5-16 indicates that the model uses the additional foreign exchange to carry out additional investment in the early periods

keeping consumption virtually unchanged in the first nine years. The additional foreign exchange makes it possible to break some bottlenecks as shown by the fact that investment increases by much more than the additional foreign exchange in the first three periods. Whereas in the Reference Solution the capacities in the Agriculture, Food, Clothing and Leather, and Mining and Metals sectors were fully utilized in the first period, now the idle capacities in this period in the Equipment and the Construction sectors are also eliminated. The total effect on the maximand of the change in foreign aid availability is to raise the value of consumption available over the entire planning period by Rs. 60,375 crores or over 10 per cent. The entire amount of that change comes in the last nine years. However, there are alternative patterns of saving and investment possible with the additional net foreign capital inflow. By changing the consumption growth constraints some part of the additionally available consumption could be shifted forward in time with resultant reductions in the maximand.

Table 5-28 shows the national income accounts of the solution G-10.2 with net foreign aid extended over the entire planning period at the rate of the Reference Solution, Rs. 1500 crores per period. The effect on the solution as compared to Table 5-16 is to increase the maximand by Rs. 5029 crores, i.e. by less than 1.0 per cent and, as would be now expected, the increase comes entirely in the last two periods. Again, however, with modification of the consumption growth constraints some part of consumption increase could be shifted forward in time.

Solutions G-11 are similar to solutions G-10 but with the initial capacities based on 1965-66 outputs adjusted for coverage on thirty-two sector basis. In solutions G-11 the initial capital is greater than in solution G-10 by Rs. 1580 crores. This leads to a difference of Rs. 17,653 crores in consumption in the sixth period. In solution G-12.0 the capital output ratio in Modern Agriculture is set at 4.0 which corresponds to the Japanese ratio as compared to 2.5 in the Reference Solution G-10.0. With the consumption growth constraints of solution G-10.0 a feasible solution did not exist. When the intra-plan growth rate in the first period is reduced from 5% per year to 3% per year a feasible solution is obtained. The increased difficulty of modernizing Agriculture due to the higher capital output ratio reduces substantially the total consumption which is provided. Consumption in the terminal period in this case is only 0.70 of the consumption in the Reference Solution G-10.0. Even then the capital stock in Incremental Agriculture is higher in G-12.0 than in G-10.0. The total terminal stock is also higher and the sectoral composition of capacities is different.

5.7 The Guidepath-II Solutions

As pointed out in discussion of the Guidepath-I Solutions one of their striking characteristics is the high savings rates which they generate which are required by the high growth rates. These rates are not imposed on the solutions but are the result of the constraints and the optimizing behavior of the model. In the Guidepath-II Model a savings constraint is added which provides an explicit policy variable and more fundamentally another way, though still indirect, of imposing on the

solution the preferences of society. The savings constraint sets a limit in each period on the maximum marginal rate of savings.[1]

Finding an "acceptable" solution to the Guidepath-II Model or a menu of "reasonable" alternatives is again an iterative process. The first step in the process is a rough, macroeconomic calculation of the potential growth rate of the system with a savings constraint using a savings-investment, Harrod-Domar type model. From this it appeared that, with a marginal net savings rate of 20%, it might be possible for the system to maintain a growth rate of 8% per year. This rate is, therefore, set as the required post-terminal growth rate for consumption in the first solution for the Guidepath-II Model. The intra-plan growth constraint on consumption is set to zero so that only monotonic behavior is required. A feasible solution is obtained under these conditions. However, in the solution the investments required for the post-terminal period are spread over the last two periods, and the savings constraints are binding in these periods. This indicates the impossibility of indefinitely maintaining

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1 The base year is taken as 1965-66 for which net national product (NNP) and net domestic savings are estimated at Rs. 19,570 crores and Rs. 2080 crores respectively. The minimum consumption for a three year period is then;

(1) $C(t) + \overline{G(t)} \geq 5520 + 0.80\ NNP(t)$ when marginal savings rate $\leq .20$

and

(2) $C(t) + \overline{G(t)} \geq 11385 + 0.70\ NNP(t)$ when marginal savings rate $\leq .30$

In the constraints embodied in the solutions, the value added by government, which is assumed to be $1.66\overline{G(t)}$ and is external to the model, was inadvertently omitted from the net national product. This has the effect of raising the permissible savings and the constraints become

(i) $C(t) + \overline{G(t)} \geq 5520 + 0.80\ [NNP(t) - 1.66\ \overline{G(t)}]$

and

(ii) $C(t) + \overline{G(t)} \geq 11385 + 0.70\ [NNP(t) - 1.66\ \overline{G(t)}]$.

the eight per cent per year post-terminal growth requirement for consumption with a marginal net savings rate of 0.20.

In the next solution, S-1.0 in Table 5-29, still using the 20% marginal savings rate, the post-terminal consumption growth requirement is reduced to six per cent per year and a five per cent per year intra-plan growth requirement is imposed. This also gives a feasible solution but again one whose character indicates that the post-terminal growth requirement is too high in the sense that it cannot be indefinitely maintained. This is shown by the decision in the model solution to carry out some investment prior to the last plan period even though the capital formed remained idle until it became necessary to fulfill post-terminal requirements. This again demonstrates the inability of the model with the 20% marginal savings rate to produce in the last plan period alone the requirements for post-terminal growth. The amounts involved are relatively small, however, and the feature disappears completely when the post-terminal growth requirement is reduced to five per cent per year.

When a solution is attempted with the required intra-plan and post-terminal consumption growth rates of solution both set at 5% per year, but the marginal net savings rate set at 15%, it is found to be infeasible. On the other hand, when the marginal net savings rate is raised to 30% with a required 5% per year intra-plan consumption growth rate but now an 8% per year post-terminal rate, the solution is feasible. This is solution S-2.0 in Figure 5-4. These solutions with some further variations are also tabulated in Table 5-29. Table 5-30 embodies the national income accounts for the Guidepath-II S-1.0 which will serve as a Reference Solution. It has 5% per year intra-plan and 6% per year post-terminal

consumption growth requirements and a maximum marginal savings rate of 20% and other conditions as in the Guidepath-I Reference Solution. The Guidepath-I and Guidepath-II Reference Solutions have interesting contrasts. The 21% to 38% average savings rates of the Guidepath-I Reference Solution cannot be realized in solution S-1.0 whose marginal savings rate is constrained at a lower level. As could be expected in the Guidepath-II Reference Solution the savings constraint operates to limit the rate of change of net domestic savings from the 10.6% average rate which obtained in the pre-plan period. Subsequently the average net savings rate never rises above 15.3% or 17.7% on a gross basis. The average gross savings rate actually achieved goes up from 14.0% at the outset to 17.7% in the last period. The savings constraint is binding in all periods.

Most of the characteristic features of the Guidepath-II Reference Solution follow from the savings constraint in a manner which is clear by contrast with the Guidepath-I solutions. With less domestic saving the rate of investment in some years is less than half that of the Guidepath-I Reference Solution. In the Guidepath-II Reference Solution the levels of consumption are higher in the first nine years and lower in the last nine years and the possible post-terminal achievement of the solution is lower. Because the level of savings is lower, investment must be lower. Consumption must be maintained, however, so fewer resources can be devoted to creating capacity in the capital goods sectors. As a result less capacity can eventually be created in the consumer goods sectors. The total value of consumption produced in this Guidepath-II Reference Solution is at Rs. 497,858 crores over the eighteen years is

16.6% less than the Rs. 595,616 crores produced in the Guidepath-I Reference Solution. Although the Guidepath-II Reference Solution has higher consumption levels in the first half of the planning period the gross national product is uniformly lower.

Some of the detailed sectoral implications of the Guidepath-II Reference Solution are indicated in Tables 5-31 through 5-37. Table 5-31 which presents the gross domestic outputs by sector indicates again a growing "industrialization" of the economy but, in comparison with the Guidepath-I Reference Solution, at a substantially slower rate.

In Table 5-32 the shadow prices of output are shown along with the shadow prices on the savings constraints. In the first period all but Housing have the same shadow price which is the same as the shadow price on the savings constraint for the first period. In this case therefore the value of an additional unit of output must be that of an additional unit of savings. The value of Housing is much higher because capacity in Housing is fully utilized and imports are not permitted. It is the bottleneck sector in the first period since with additional Housing capacity more consumption could be provided which in turn would generate more income and consequently more savings. In the second period the shadow prices of output of all the sectors are the same as the shadow price on the savings constraint for the period. From third period onwards other constraints become more significant and the savings constraint though still binding is no longer so completely dominant.

The use of foreign exchange for non-competitive and competitive imports and the shadow prices of foreign exchange for the Guidepath-II Reference Solution are shown in Table 5-33. In the first period

non-competitive imports are concentrated in consumer goods sectors in order to raise aggregate consumption, net national product and savings. After the first period Mining and Metals continues to be the sector toward which foreign exchange is directed after non-competitive imports requirements have been satisfied. The shadow prices on the foreign exchange balance indicate a somewhat lesser foreign exchange stringency in the first periods as compared to the Guidepath-I Reference Solution and a slightly greater stringency in the latter periods.

Table 5-34 presents the sectoral distribution of consumption in each period and the shadow prices on the consumption growth constraint and the savings constraint. The higher levels of aggregate consumption in the first periods lead to an earlier shifting of the composition of consumption away from agricultural products relative to the Guidepath-I Reference Solution. This shifting slows down in the latter periods as aggregate consumption grows more slowly. The consumption growth constraint is binding only between the second and third periods and the fifth and sixth periods.

The total availability of capital and its use are shown in Tables 5-35 and 5-36. These tables also reflect the relative emphasis of the Guidepath-II Reference Solution on consumer goods rather than capital goods. However, the productive capacity in all sectors grows more slowly in the Guidepath-II as compared to the Guidepath-I Reference Solution. The idle capacities in the first two periods, before the proportions in which capacity is originally available can be adjusted to requirements, as shown by the ratios of idle to total capacity in Table 5-36, indicate

substantial excess in the capital goods sectors and their major suppliers and bottlenecks in the consumer goods sectors. In the Guidepath-I Reference Solution idle capacities were eliminated by the second period.

Table 5-37 which lists the new capacity by period and sector confirms the previous contrasts in the solutions. Agriculture, Housing and Food and Clothing account for over fifty per cent of the total capacity in all periods whereas in the Guidepath-I Reference Solution their total proportion was a third or less except at the very end of the planning period when consumption was rising rapidly. The total new capital formation in the Guidepath-II Reference Solution varies from 27% to 60% of that of the Guidepath-I Reference Solution in corresponding periods.

Differences among the Guidepath-II solutions with various constraints are illustrated in Table 5-29. Most of these are quite predictable. The effect of increasing the marginal net savings rate, for example, in solution S-2.0 relieves the savings constraint somewhat and, as a result, the total and final levels of consumption rise. The post-terminal growth requirement of 8% in this solution as compared to 6% in the Guidepath-II Reference Solution offsets this effect somewhat.

The comparative effects of increasing net foreign capital availabilities are not so obvious. It might be thought, for example, that such an increase would always benefit most the solution with the tightest domestic saving constraint. In fact, however, when the specified net foreign capital inflow is doubled over four periods, the value of maximand goes up more when the marginal savings rate is 30% than in the solution in which it is 20%. The higher marginal savings rate permits a greater plowback of increments of output into investment which will in turn

yield even more consumption in the future. The effect is slightly the reverse when the net foreign capital inflow is extended at the same rate for six periods. This is because in the last two periods the investment emphasis has shifted to the consumer goods sectors. The higher post-terminal growth rate in the solution with the marginal savings rate of 30% absorbs a larger amount of the additional foreign exchange.

5.8 The Guidepost Model Solutions

Once a long run guidepath is selected the next step is to check its short run feasibility and, if feasible, to determine the year-by-year allocations necessary to achieve it. This is the task of the Guidepost Model with year-by-year accounting and gestation lags. Prior to the Guidepost solution it cannot be known whether a short run plan using the guidepath as a target will do better or worse with respect to the maximand than the Guidepath Model over the same years. As pointed out previously time aggregation not only provides unwarranted flexibility but also creates undue rigidity and the net effect cannot be predicted from qualitative considerations.

The Guidepost Model can be used in a variety of ways to test and detail a Guidepath solution depending on what short run constraints and targets it is desired to enforce. In the applications to be described, since emphasis has been placed on achieving targets, the minimum intra-plan consumption growth rates are reduced to 2.5% per year. When the targets are taken from a Guidepath-II solution, the savings constraints of that solution are also enforced. The capital stock targets and post-terminal conditions are interpolated from a Guidepath solution. In order

to fit the Guidepath results most conveniently the planning period is set at six years.

The third period capital stocks in the Guidepath Model solutions correspond to the stocks in the period covering 1972-73, 1973-74 and 1974-75. This capital stock is taken to be the target capital stock in the Guidepost Model for the year 1973-74 which is the eighth year starting from 1966-67. The capital stocks for the seventh and the ninth years are projected from the initial stocks of 1966-67 and the growth rates implied by the eighth year targets. In projecting the targets for Incremental Agriculture, whose initial capacity is zero, the growth rate between the third and fourth period in the Guidepath solution is used. To project the initial capital in process, however, the intra-plan growth rates of the Fourth Plan Target Model solutions are used. This establishes comparability with the initial conditions of the Target and Transit Model solutions for the Fourth Plan period as well as the Guidepath solution. Thus the maximum potential capacity in the second year of a Guidepost solution, 1967-68, is the same as the capacity in the first three year period, 1966-69, of the corresponding Guidepath solution.

The Guidepost Model has little freedom or scope for choice left to it. As in the Target Model the initial conditions determine the maximum capital stocks for the first three years and the terminal conditions determine these stocks for the last three years of the Guidepost plan period. The minimum consumption level for the first year is set and, while the solution can do better it is not allowed to do worse than stipulated. If the Guidepost solution is feasible its general character is, therefore, predetermined by the Guidepath solution on which it is based and will contain no surprises.

Solutions are feasible for the Guidepost Model corresponding to the Guidepath Model solutions G-10.0, G-12.0. However, the Guidepost solution corresponding to Guidepath solution S-1.0 is infeasible. The maximum, marginal net savings rate of 0.20 in this case is too low to allow completion of the initially endowed capital in process in the Guidepost solution whereas in the Guidepath solution the initial capital capacity endowment already embodies the completed capital in process. When the marginal savings rate in the first two years is allowed to rise to 24% and 22%,[1] the Guidepost solution P-3 is found. Alternatively, corresponding solutions could have been found by proportional reductions in the targets or by relaxing the consumption growth or other constraints. Tables 5-38, 5-39 and 5-40 present the annual national income accounts for these Guidepost solutions P-1, P-2 and P-3, respectively.

In the Guidepost solutions as in other cases the rate of growth of national product is neither a simple, linear nor an exponential function. However, if such a pattern were desired, to provide for smooth growth in employment for example, it could be imposed as a constraint though relaxation of some other constraint might be necessary to achieve the guidepath. The savings and investment rates of the corresponding Guidepath and Guidepost solutions are more or less the same over comparable periods as are the sectoral resource allocations which lie behind the aggregate results.

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1 Even then not all the initial capital in process that could have matured in the third year are completed, and solution P-3 has lower initial capacities than would correspond to S-1.0.

Table 5-41 summarizes some of the major aspects of the Guidepost and corresponding Guidepath solutions. As shown in this table, the Guidepost solutions for targets taken from the two Guidepath-I solutions perform better, in terms of the consumption produced, than the Guidepath solutions themselves over the same period. However, the differences are slight and, in these two cases, the time aggregation in the Guidepath models does not seem to have significant effects. That was not the case with the Guidepath-II solution but this can be ascribed to inconsistencies in the implied marginal savings rates necessary to complete the assumed initial capital in process and the constrained savings rate of the Guidepost solution.

5.9 Comparison of the Guidepath Solutions and the Fourth Plan Target Model Solutions

Since the capital stocks generated by a Guidepath Model solution for its early years are consistent with an explicit optimum long run growth path, it is interesting to compare these stocks with those called for by the adjusted Fourth Plan targets. Table 5-42 presents capital stocks for 1971-72 interpolated from several Guidepath solutions and the adjusted Fourth Plan target stocks.[1] With similar capital coefficients the Guidepath-I solution generates higher capital stocks than the Guidepath-II solutions in all but the three major consumer goods sectors,

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1 The adjusted Fourth Plan capital stocks in Agriculture are further adjusted to provide the same output capacities as would be provided if the two activities of the Guidepath Model had been used. The adjustment adds Rs. 2306 crores to the capital stock in this sector. In Transport output target is multiplied by its long term capital output ratio, 4.329, of the Guidepath models.

Agriculture, Food and Clothing and Leather, and Housing. The total capital stock of Guidepath-I solution G-10.0 is 17% larger than that of Guidepath-II solution S-1.0 in which the marginal savings rate is 20.0%. In solution G-12.0 in which the capital-output ratio of modern agriculture is raised from 2.5 to 4.0, the capital stock in that sector is higher than in the Guidepath-II solutions but its effective productive capacity is lower. The differences in the sectoral stocks in the Guidepath-I and II solutions are most striking in Mining and Metals and Equipment where they are close to 100% and in Construction where the difference is about 60%.

The size and composition of the extrapolated Fourth Plan target stocks correspond more closely to those of the Guidepath-I solutions than to stocks generated by the Guidepath-II solutions. The correspondence is far from exact, however. In Mining and Metals the Target Stock is about 74% of that of the Guidepath-I solutions though about 60% more than that of the Guidepath-II solutions. In the Equipment sector the Target and Guidepath-I stocks are similar as they are also in Agriculture, Food and Clothing, Transportation, Construction and Housing. In the other sectors the Target stocks are moderately to substantially higher than those of the Guidepath-I solutions and the difference in Chemicals is particularly striking. The overall levels of the adjusted Target stocks are roughly comparable to those of the Guidepath-I solutions, though the sectoral compositions are somewhat different. The adjusted Target stocks are higher than those of the Guidepath-II solutions except in Housing and Agriculture. The overall difference is about 20%.

The sectoral proportions of capital stocks are also shown in Table 5-42. Comparing the Guidepath-I and II solutions with similar capital-output ratios it is clear that the Guidepath-II solution with higher marginal savings rate of 30% resembles the Guidepath-I solution slightly more than the solution in which the marginal savings rate is 20%. It is understandable that this should be so since the savings requirements of the Guidepath-I solutions are much higher than in either of the Guidepath-II solutions. The greater relative emphasis on consumer goods in the Guidepath-II solutions leads to a higher proportion of capital stock in Chemicals than in the Guidepath-I solutions to supply the input requirements of Agriculture. The proportions of total stock in Electricity show an unexpected constancy. In general the higher the rate of savings in the solutions, the higher is the proportion of capital stock in the capital goods producing sectors and their major suppliers.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Infinite learning does not aid
To virtue those who are afraid;
As men with lamps no sooner find
Lost objects, if those men are blind.

--The Panchatantra

The objective of this study has been to develop and test models for understanding and planning the sectoral and temporal allocation of resources for economic development. The analytical technique of the models is that of linear programming and it is used in the context of the theory of capital accumulation and growth. Like all such models they are simplifications of reality in their theoretical structure, their empirical descriptions and their development criteria. The models are applied to India in order to examine the implications of the Third Five Year Plan and a proposed Fourth Five Year Plan. They are also used with Indian data to generate long-term plans extending up to thirty years and to construct short-term plans consistent with the long-term plans. Since our purpose has been that of a pilot study we have not elaborated all the features which could be provided in the models. The most obvious example is in the limited number of sectors with which the solutions are performed. Increasing the sectoral detail is a straightforward operation, however. Likewise we have provided for technical change only in the agricultural sector, though the treatment can be generalized. Although it has not been our primary goal to generate currently applicable policy recommendations, it has been our conviction that the test of models is in their actual confrontation with practical problems and we have tried in a modest way to do that.

Three types of judgments emerge from the models and their solutions:

(1) observations on Indian plans,

(2) judgments as to model building techniques and the relative merits of alternative model formulations as a basis for making economic policy, and

(3) insights into the characteristics of economic growth.

In this final chapter we shall summarize the results of the previous chapters and make observations in all three areas.

6.1 Observations on Indian Plans

The model solutions provide the basis for judgments about the Indian economy but the judgments must remain tentative because of inadequacies in the models' structure as well as limitations of data. Some of the structural inadequacies such as the fixed composition of consumption and fixed technical coefficients are less severe for the short than for the long run. Other inadequacies of the analytical framework are more important in the short than long run. Likewise, long and short run results have different degrees of sensitivity to various data estimates. Errors in the estimates of initial endowments, for example, which may create bottlenecks will have a profound influence on a five year plan but relatively little influence on the general outlines of policy contained in a thirty year plan. The alternative solutions of the Target Models for the Third and Fourth Plans which indicate the sensitivity of the results to changes in various exogenously specified quantities and parameters also demonstrate the difficulty of drawing unequivocal conclusions from the solutions.

As should be the case for five year targets the justifications of the Indian plans have been couched in long run terms. The Target Model cannot and is not intended to examine the long term rationale of the plans but only to investigate the implications for the plan period itself of exogenously stipulated targets. Analysis of the short run implications of such targets does not require a long term model. Resources cannot be

transferred from the future to the present and short plans which are infeasible due to lack of resources do not become feasible in a long term analysis. If solutions cannot be found with the plan targets imposed then that indicates technical infeasibility with the assumed parameters, constraints and model structure. The result can be changed by modifying the assumptions so the issue of feasibility comes always to hinge on a judgment as to whether the parameters and allocations which are necessary for success will in fact be achieved. The difficulties which we have stressed in basing judgments on evidence from the models' solutions are not a special feature of the models but are intrinsic to the problems. The models only force a greater awareness of alternative possibilities by being more comprehensive and explicit as compared to less detailed models whose structure permits a greater degree of ambiguity. Yet many of the qualifications of the present study which are necessary because of our dependence on secondary data sources could be overcome in India, at least, where the potential exists for better and more comprehensive statistics.

6.1.1 Third Five Year Plan

(a) Analysis of the Third Plan with the Target Model indicates that its targets were technically infeasible in the sense that no solution is possible for these targets using the Reference Set of coefficients and parameters which we believe to be at least moderately optimistic. Only with a more optimistic set, i.e. with improved efficiency in implementation reflected in shorter gestation lags, and with lower capital and inventory coefficients, is a feasible solution obtained. This solution, however, does provide

consumption levels which are close to those projected by the Third Plan itself.

(b) The investment and domestic savings requirements in the Target solutions which are obtained are substantially higher than those projected in the Third Plan itself. This remains true even when the targets in all sectors are reduced by 4% and solutions are found using the Reference Set of parameters. However, the investment requirements estimated by the Target Model for a set of targets projected as the "likely achievements" for 1965-66 are also higher than the projected actual investment levels for the Third Plan period. Though this last result may be explained in a variety of ways, as discussed in Chapter 4, it suggests the possibility that the Target Model solutions may overestimate the investment requirements of the Third Plan. On balance, though the results are not unequivocal, we believe that they throw doubt on the operational feasibility of the Third Plan targets in the sense that adequate provision was not made in the Plan for investment and domestic savings consistent with the targets.

This is not a new criticism of the Third Plan but evaluation using the Target Model does not depend on the estimation of a single aggregate capital-output ratio but on many parameters. In a sense the scope for controversy is broadened but it is also more focused because more of the relevant issues are made more explicit. The Third Plan targets in general have not been achieved but that cannot be taken as "proof" that the Target Model implications are correct. Other circumstances can account for the shortfalls which have occurred in the Third Plan period, and, in fact, most probably did contribute to these shortfalls.

Unfavorable weather hampered agricultural production and the hostilities with China and Pakistan undoubtedly forced diversions of domestic capacity and foreign exchange resources from their originally intended uses. Yet it is also true that the savings rates actually achieved in the Third Plan period and projected for the Fourth Plan are substantially less than those which the Target Model indicates as necessary for the fulfillment of the targets. Either the Target Model calculations are wrong or the targets are unachievable with the savings projected in the Plan.

6.1.2 Fourth Five Year Plan

In this series of tests the Plan targets, themselves, are uncertain as they are estimated from an incompletely specified set proposed in April, 1964 by the Perspective Planning Division of the Planning Commission. They are, therefore, neither official nor necessarily the comprehensive goals of the P.P.D. itself. The adjustment procedure extends the specified targets for the organized sector to the unorganized sector. One method of adjustment leads to higher terminal stocks than an alternative adjustment method. The policy issue involved is the extent to which the unorganized sector will want or be allowed to expand to keep pace with the organized sector.

(a) Application of the Target Model to both sets of adjusted targets for the Fourth Plan leads to technically feasible solutions under a wide variety of exogenously specified quantities.

(b) On the question of operational feasibility results are even less clear than for the Third Plan but in this case also the Target Model solutions raise doubts as to the operational feasibility of the adjusted

proposed Fourth Plan targets. In most of the solutions, the targets require more investment and domestic saving than were projected. In the solution in which the calculated levels of investment and saving are more or less equivalent to the proposed levels the adjusted targets embody the lower goals for the unorganized sector and as well require particularly optimistic projections of agricultural output and inventory requirements. In addition this last solution also foresees reductions in growth rates in all the sectors after the Fourth Plan. The latter assumption reduces the amount of investment required in the Fourth Plan for the Fifth Plan period. The various alternative calculations and sensitivity tests lead us to conclude that the proposed Fourth Plan Targets as adjusted by us may again be operationally infeasible. The fundamental reason for this is finally, relatively simple: the total amount of investment and, therefore, of domestic savings required by the Plan's adjusted targets as computed in the comprehensive calculations of the Target Model is more than that projected in the Plan calculations. The Target Model, however, does not indicate exactly how the Indian economy would perform in the course of "underachieving." An infinite number of adjustments are possible and the combination of feasible sectoral outputs which will in fact be produced cannot be foreseen with the model. That depends on the relative success of the different sectors in exercising entrepreneurship, mobilizing investment, gaining access to foreign exchange and so on.

(c) The Fourth Plan target solutions indicate that the import substitution program is a crucial factor, for unless import requirements are reduced foreign exchange shortages set a limit to the overall

performance of the economy. This again is hardly a new idea but the analysis both relates it to the size and composition of the targets and is more specific.

(d) The Target Model solutions raise many questions which could not be answered in this study but whose relevance to the outcome of the Plans is made more clear by the great amount of detail generated by the analysis. Only a few examples will be repeated here. Capacity in the Construction industry is often a bottleneck in the early years of the Target Model solutions which indicates the importance of a careful study of this sector and its requirements for expansion. The importance of foreign exchange allocations is made graphic in the alternative solutions. The output targets in Mining and Metals often appear low in relation to what is required by other targets and, for this reason as well as its high direct and indirect costs, the solutions often indicate the desirability of larger foreign exchange allocations than permitted by the constraints. This again suggests the need for more detailed studies.

(e) The Transit Model is a relatively short-sighted model. Since a provision for increasing the growth rate in the post-terminal future, beyond the specified post-terminal growth rate is not made, the emphasis on capital goods sector is less in the Transit Model solutions for the Fourth Plan period than in the adjusted Plan Targets. Thus the Transit Model indicates the effects of a short-run consumption oriented plan. An intra-plan growth rate of 5% in consumption is achieved and provision is made for at least the same post-terminal growth rate. If such growth rates in consumption are to be maintained with roughly the existing composition and if savings cannot be increased as much as the plans require, the

relative proportions of the targets must be adjusted toward the consumer goods sectors as in the terminal stocks generated by the Transit Model solutions.

(f) The short run analysis of the Target Models cannot reveal the long run implications of a set of five year plan targets. Similarly the Transit Model is not a satisfactory method for setting targets whose implications will last long into the future. These issues require an expressly long term approach such as embodied in the Guidepath Models covering eighteen to thirty years. No sufficiently explicit long term plans comparable to the Third and Fourth Plan targets were available to us for testing. The solutions to the Guidepath Models are, therefore, intended mainly to illustrate how these Models can be used for consistent long and short run policy-making. Nonetheless Indian plans are based on long run objectives and a comparison of the character of the Guidepath Models solutions with the adjusted targets proposed for the Fourth Plan does provide a basis for conjecture about the long term path with which those targets are consistent. The level and sectoral composition of the adjusted Fourth Plan targets is more comparable in corresponding years to the level and composition of capacity created in the solutions to the Guidepath-I Model than to the capacity in the Guidepath-II Model.[1] In Guidepath-I Model Reference Solution in which the consumption path is smoothed by being constrained to grow at increasing rates the average net savings

1 The existence of a relationship between the composition of output and the savings rate must certainly have been remarked on many times though perhaps not in the context of a many sector optimal growth model. In the context of a simpler, two sector model a similar point has been made by Marvin Frankel, "Producer Goods, Consumer Goods and Acceleration of Growth," The Economic Journal, LXXI, March, 1961, pp. 1-19.

rates range from 18.8% to 36.8%. In the Guidepath-II Model solutions the marginal net savings rates are constrained to 20% and 30% and the average rates never rise above 15.6% and 21.4% respectively. Compared to the Fourth Plan targets, however, the Guidepath-I solutions provide much more of Mining and Metals capacity and much less of Chemicals capacity. This may be the result of a different long term rationale behind the targets or of discrepancies in the treatment of import substitution though that is to some extent allowed for in the Guidepath Models and imports tend to be concentrated in Mining and Metals anyway.

6.2 Linear Models and Economic Growth

In the Guidepath Models our paramount objectives are those of developing techniques of generating alternative plan outlines and illustrating the growth paths which might be achieved under various circumstances.

(a) As is well known, in linear capital growth models with linear objective functions, consumption is concentrated at either the beginning or the end of the planning period depending on the discount rate and the productivity of capital. When consumption is concentrated toward the end of the planning period, in a finite horizon model the precise period in which the shift toward higher consumption rates occurs is again a function of the discount rate.

Though flip-flop behavior remains an underlying tendency in the multi-sector Guidepath models it is modulated not only by the constraints imposed specifically for that purpose but also by other essential features of the models. The multi-sectoral character of the model with different input requirements for each sector and changing sectoral

composition of various demands over time is a source of effective non-linearity. The two activities in Agriculture with a gradual shift to a higher cost activity imposes diminishing returns in this sector. In addition non-linearities are also imposed in the exogenous specification of requirements for the export sectors, in the depreciation levels and in the projections of foreign capital inflows as well as in changes over time of some of the parameters such as import and inventory coefficients. The result of all these non-linearities is that even when a large proportion of total consumption is postponed to the end of the plan period, some increase in consumption also takes place in the earlier years and the model does not concentrate its shift to a consumption emphasis within a single period.

(b) The flip-flop behavior is also effectively controlled by imposing constraints on the minimum growth rate of consumption in each period of the plan. The intra-plan consumption growth constraints when binding compel the time path of consumption along a specified path. These constraints combined with the post-terminal growth requirements can be used to generate different time shapes of consumption. As a result of these conditions the flip-flop behavior never takes the extreme form it does in simpler models and, in fact, becomes so controlled that it is often difficult to discover what the tendency is.

The demonstration in the alternative Guidepath-I solutions of the achievement of a more or less smooth growth path by the use of intra-plan consumption growth requirements in conjunction with the post-terminal growth requirements is of methodological interest. Perhaps, of practical interest is the fact that the growth rates of gross national product

achieved in this way are high by comparison with India's or almost any other nation's performance. These rates are generated even with diminishing returns in the important Agricultural sector, elimination of net foreign capital inflows after twelve years and no benefits from external economies or technological change. There are, of course, no labor or natural resource constraints except the land limitation in Agriculture. Much of the performance is due to the extraordinarily high savings rates. In an unconstrained flip-flop solution everything above minimum consumption would be saved for the final payoff. With steadily increasing intra-plan consumption requirements some of the final jackpot is traded for additional consumption in each plan year. If the savings rates themselves are not constrained both increasing intra-plan consumption and the higher post-terminal consumption growth requirements can be fulfilled.

(c) The Guidepath-I Model was solved in six and ten period versions covering eighteen and thirty years respectively. The differences between the versions for the first four periods or twelve years were slight. After that the discrepancies were clearly due to the terminal conditions imposed on the shorter-term model. This similarity in the early periods is an outcome of the imposition of the consumption growth constraints. When such constraints are used a planning horizon of roughly twenty years appears to be adequate at least for parametric variations.

(d) Solutions to the Guidepost Model performed slightly better in terms of consumption than the solutions of the corresponding Guidepath Models for which they provide the details of consistent yearly allocations. The effect of time aggregation in these models therefore appears to be small. The result may not be generalized, however, since it depends upon the particular values of the parameters.

6.3 Suggestions for Improvements in Models

Though not intended to be applicable only to India the models presented are more relevant to that country's circumstances than to many other countries. Even with respect to India a variety of further structural generalizations are possible which would improve their usefulness as planning tools. Most of these were not embodied for lack of empirical information or because of the increased computational burden which they would create. For example, one of the most obvious omissions is the complete lack of consideration of labor requirements. They could be computed by use of productivity coefficients as a reasonable approximation. It is more difficult to find a satisfactory first approximation for the labor supply relations, however. The consistency of manpower plans with the overall plan could be tested by calculations exogenous to the optimizing model. Differentiation of capital by vintages, each with its own input coefficients, would be another improvement in the present structure but it would require separate accounting for the capital of each vintage. With such accounting more freedom could be permitted in the capital gestation process. Depreciation could be made a function of the existing stock or of output if either method is clearly preferable to its exogenous specification. To take economies of scale into account minimum investment level constraints can be imposed.[1] Many of these and other improvements would be desirable and important in the context of a more disaggregated system. In such a system some degree of consumption substitution could be permitted by setting permissible ranges for each sector.

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1 This can be used only under limited circumstance. In general integer or non-linear programming would be required for this.

The same device could be used to investigate sectoral comparative advantage for exports. On the savings side, if income distribution data could be used to allocate national income, savings relations appropriate to each income category could be applied. This list of potential improvements in the models' structure serves also to indicate the limitations of the present structure.

6.4 Growth and Savings

Since the theoretical structure of the Guidepath Models is an extension of existing economic theory rather than an innovation, surprises are not to be expected in the qualitative results.[1] The sectoral and temporal detail which the Models' solutions generate do make those results more graphic and relevant to the debates on growth strategy. These debates have many common issues, whether in the context of advanced or less-developed, mixed capitalist or socialist economies. They are concerned with relatively abstruse issues such as the "optimum" rate of saving and such practical questions as the effects on growth of a change in the marginal savings rate and the best relation between industrialization and agricultural expansion. The answers of the Guidepath Models are by no means final as they remain highly simplified versions of reality but they do approach practical answers to these and other questions.

In the Guidepath-II formulation the savings rate is directly controlled by a constraint. This relates marginal savings and, therefore,

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1 The literature on the theory of economic growth is rich in illustrations of single sector models with optimal growth paths having some of the properties of the multi-sectoral Guidepath Model. We should particularly like to cite, however, the paper of Richard Goodwin, "The Optimal Growth Path For An Underdeveloped Economy," The Economic Journal, LXXI, Dec., 1961, pp. 756-774.

consumption to net national product in a linear relation. It combines an effective demand condition with the previous supply conditions. Increases in net national product from any source, e.g. growth in consumption or investment production lead directly to further increases in consumer demands which must be met. This additional constraint can be viewed as a behavioral relation imposing institutional restraints on policy decisions.

Several different marginal savings rates were tried in Guidepath-II solutions, starting from the average savings rates achieved in the last years of the Third Five Year Plan. The constraints embodying these savings rates were always binding even up to a marginal net savings rate of 30%. Thus, their imposition had a significant effect in reducing the overall growth rates achieved as compared to Guidepath-I solutions in which the unconstrained marginal net savings rates often exceeded 45%.

The sectoral allocations of the Guidepath-II as compared to the Guidepath-I Model reflect the effects of the overall savings constraint. Both the Guidepath-I and Guidepath-II Models generate a long term program of structural change in the economy leading to an increasing degree of industrialization. In the Guidepath-I versions the change is more drastic and concentrates on the capital goods producing sectors and their major suppliers. With less savings allowed and consumption related to net national product in the Guidepath-II version, the emphasis in investment and production shifts away somewhat from the capital goods toward the consumption goods industries.

The overall contrasts between the Guidepath-I and Guidepath-II solutions are quite striking and may help explain the different experiences

of countries which have during certain periods developed quite rapidly under the forced draft of tight controls on domestic consumption and those economies which have been unable or unwilling to force equally high savings rates. The former have emphasized their capital goods sectors, neglected relatively the consumer goods sectors and achieved high overall rates of growth while improvements in the standard of living took place at a slower pace. The Guidepath-I Models, however, demonstrate the potentiality of both higher consumption growth rates and high overall growth rates associated with relatively high savings rates. The consumption provided in the Guidepath-II Model solutions in which savings are constrained to lower levels very quickly falls behind the achievements of most of the Guidepath-I solutions.

The choice of a long term growth path depends on individual and social preferences and in the Guidepath Models the savings constraints may be used to reflect these preferences as well as institutional limitations. In this respect the quotation from Alice in Wonderland with which Evsey Domar began his classic article on economic growth may be recalled. The Red Queen observes that in her country,

> "it takes all the running you can do to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

The results achieved with the Guidepath Model solutions, tempt us to add, "Up to a certain rate, the faster you run, the easier it will be." That the limit rate of savings may be quite high is indicated by the results of the Guidepath-I Models.

The difficulties of running fast in terms of saving, which are well-known, may be reduced by promises of rapidly growing consumption.

But the dangers should not be underestimated of setting targets which are consistent with high savings rates and achieving neither targets nor savings rates or of only achieving the savings rates. The results may well be worse than if initial ambitions had been more modest.