A PROGRAMMING MODEL OF INCOME DISTRIBUTION

THE EFFECTS
OF
ALTERNATIVE INCOME DISTRIBUTIONS
ON RESOURCE ALLOCATION
IN INDIA

by

ARGHYA GUHA, M.A.

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AUTHOR: Arghya Guha, B.A. (Calcutta University)

M.A. (Delhi University)

M.A. (McMaster University)

SUPERVISOR: Professor S. Mestelman

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Abstract

In the thesis, we examine the effects of alternative income redistribution schemes on the optimal pattern of allocation of resources. We also identify the sectors in the economy which are under strain when these redistribution schemes are implemented and the years in which the strains are felt most. We find that the redistribution of income between the lower and middle income groups in the rural sector leads to the maximum value of the objective function, which is a discounted sum of gross outputs. Alternatively, the redistribution of income between the upper and middle income groups in the urban sector consistently leads to low values of the objective function.

We also conduct tests to determine how sensitive these results are to changes in the values of the parameters assumed. The results regarding the relative desirabilities of various redistribution schemes are found to be rather insensitive to changes in the values of the social discount rate and the savings rate. A higher availability of foreign aid increases the desirability of urban redistribution schemes. Modest requirements of post-terminal growth lead to infeasibilities for most redistribution schemes, as well as the reference solution, which assumes the status quo distribution of income. The only feasible redistribution schemes are those which redistribute incomes between the upper and middle classes, and the middle and lower classes in the rural sector. This leads us to recommend rural redistribution as not only a desirable policy, but as a necessary prerequisite to obtaining modest growth rates in the post-plan period.

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CHAPTER 1

Introduction

I

The distribution of income is a very important, but often neglected topic of Economics. It is also a topic which generates a great deal of interest among people from all walks of life. The intensity of interest is often fraught with emotions, and the differences of opinion about this subject are the basis of important ideological differences which exist among the countries of the world. The determination of the "ideal" distribution of income cannot be done without making value judgments, and is therefore an issue which may never be irreconcilably settled. The preceding statement, however, does not justify the complete shelving of the distribution issue since controversies, conflicts and very often bloodshed have resulted when people have thought that the distribution of income and wealth has not been "right". We therefore note that even though it is difficult to identify an "ideal" distribution of income, people generally feel strongly about attaining what they think is the "ideal" distribution, and therefore attention should be paid towards obtaining a distribution which is generally acceptable.

In India, at a philosophical level at least, the consensus of opinion has been that the distribution of income is too unequal to be compatible with any concept of justice. The government's policy should

therefore be geared towards redistributing income from the haves to the have-nots to obtain a more egalitarian society. The effects of such redistribution schemes, however, are far-reaching since different income groups have differing savings rates and consumption patterns. It is therefore not enough to merely redistribute income; one has to also study the effect that it has on the demands for various commodities, and therefore on the pattern of allocation of resources. If different redistribution schemes imply significantly different resource allocations, then other aspects of the economy have to adjust accordingly. It is these implications of income redistribution which we examine in this study.

We make this examination in the context of a planning model of the Indian economy, assuming that the government is able, by some unspecified policy measures to control production in the various sectors of the economy. Both in order to determine the best policy of the government and to evaluate the efficacies of the various income redistribution schemes vis-a-vis each other, some kind of criterion function has to be postulated, and this, as shall see, leads to problems. Such a function should be defined in the utility space, but even if individual utilities are measurable, they are not comparable, and it is difficult to translate them into social utility. We therefore have resorted to posing the criterion function in terms of the total physical production which takes place during the plan period. We assume that the plan is formulated by maximizing this criterion function, given the structure of a model of the Indian economy.

The model:

The constraints of the model have to be satisfied if it is to be consistent. There are five types of constraints in the model. The are:

(1) intersectoral and intertemporal consistency constraints, as given by the input-output matrices;

(2) foreign exchange constraints which require that the total supply of foreign exchange be greater than, or equal to the total demand for them;

(3) initial capital constraints which tell us that production in the early years is limited by the amount of capital in existence in the pre-plan period;

(4) terminal capital requirements which are necessary to ensure a required rate of post-terminal growth; and

(5) minimum output constraints, representing diverse economic and non-economic factors which are not explicitly considered, but which require that outputs in certain sectors cannct fall below certain minimum levels.

Given the above system of linear constraints, we maximize the linear objective function for various distributions of income. The different income distributions affect the demand side of the first type of constraint, and therefore result in solutions which differ from each other. By comparing the values of the objective functions in these cases, we can determine the kind of redistribution scheme which results in the maximum amount of aggregate output over the plan. This can, in a sense, act as a

criterion for determining the relative efficacies of various income redistribution schemes, while the solution values of gross outputs indicate the pattern of resource allocation necessary to put them into effect. The shadow prices obtained by solving the dual to the problem, informs us about the relative importance of the various sectors in contributing to the objective function.

Having concluded this set of exercises, we vary some of the parameters of the model to find out how sensitive our results are to changes in them. The parameters varied are:

(1) the social discount rate;

(2) the post-terminal growth rate;

(3) the availability of foreign aid; and

(4) the savings rate.

We have divided the households into six income groups. These consist of an upper, a middle and a lower income group in the rural and the urban sectors separately.

The main results obtained may be summarised very briefly. We find that redistribution between the two lower income groups leads to higher values of the objective function than redistribution between the two upper income groups. Moreover, redistribution in the rural sector leads to higher valued objective functions than redistribution in the urban sector. Our results are insensitive to changes in the social discount rate. The imposition of modest post-terminal growth rates leads to infeasibilities unless rural income redistribution takes place. The redistribution of incomes between the two upper groups becomes relatively less

attractive when the availability of foreign aid is reduced. The assumption of higher savings rates (the average savings rate being assumed equal to the actual marginal savings rate) allows the complete equalization of all incomes to be feasible. Rural redistribution still yields higher valued objective functions as compared to urban schemes; redistribution between the two lower groups continues to dominate over redistribution between the two upper groups on the same criterion.

The results obtained are subsequently used to derive some policy conclusions.

II

The contents of the following five chapters may be briefly summarised in this way:

Chapter 2: a brief consideration of the meaning of "development", and an explanation as to why planning may be necessary for economic development. The chapter concludes with a description of Indian planning.

Chapter 3: a survey of the literature on optimum savings and the Leontief input-output system. This is followed by a survey of models which have used the linear programming technique to represent and solve economic problems

Chapter 4: a presentation of a linear programming model of the Indian economy which incorporates the distribution of income as part of the input-output system.

Chapter 5: a presentation of the results obtained from the exercise of Chapter 4, and the policy conclusions derived from them.

Chapter 6: a summary of the results obtained and concluding remarks.

In chapter 2, we begin by noting that India is an extremely poor country, but has acquired the potential to develop. What is feared is that the development process may be too slow for certain sections of the populace who are struggling desperately to survive. The need therefore arises to focus more attention on them to ensure that the gains obtained from planning are divided equitably. This is not only desirable from the standpoint of justice, but may be necessary to prevent political and economic chaos. We conclude that India is a country which needs planning if her economic development is to proceed smoothly. The final section of the chapter is devoted to a study of the Indian plans as they were actually formulated, and the results of their implementation. We note that, although significant gains have been achieved, the performance of the Indian economy has been, in general, below expectations.

The first plan is the only one which can be termed "successful". Modest targets, unutilised capacity and favourable weather conditions contributed to it. From then on, the plans have been only partial successes. A variety of crises have affected the Indian economy, and progress has been slow. On the positive side, however, we find that a broad industrial base has been built and significant strides taken in an attempt to obtain econ-

omic independence, which is a prerequisite to true political independence.

Chapter 3 begins with a study of various types of optimal savings models. The results of the earlier Ramsey and Tinbergen models are worked out in some detail, and those of later contributors — Koopmans, Malinvaud, Mirrlees, Chakravarty, Maneschi, von Weizsäcker, Inagaki — are merely noted. The study is intended to point out the manner in which an optimal time path of physical production can be obtained from a given utility function. It highlights the difficulties inherent in obtaining a reasonable time path for output in physical terms when the function to be maximized is defined in the utility space. We conclude that it is more practicable to define our objective function in physical terms.

We then move over to a survey of the literature on the static and dynamic Leontief input-output models. These form a very important part of our constraint system, and thus a study of some of the properties of the system is made.

We finally undertake a survey of the various linear programming models which have been built (by Chenery, Bruno, Manne, et al.) and the problems that they have tried to solve. We note that no model has used the linear programming technique to tackle problems of income distribution in any way. This is a gap which we attempt to fill in chapter 4.

Chapter 4 consists of a detailed description of the model. The discounted sum of gross outputs over the plan years is maximized subject to the constraints that

(1) the supply of sectoral outputs are greater than or equal to the total demand for them;

(2) the supply of foreign exchange is greater than or equal to the total demand for it;

(3) the output during the first two years is less than or equal to a maximum permissible amount, which is given by the total stock of capital available in the pre-plan year;

(4) enough capital is available in the last year of the plan to meet certain post-terminal growth requirements; and

(5) the sectoral outputs in each year are greater than or equal to certain minimum permissible levels, given by factors, economic and non-economic, which are not explicitly considered by the model.

Several kinds of redistribution schemes are considered. They include redistribution within the rural and urban sectors, both separately and simultaneously. Redistribution is carried out between the upper two income groups, the lower two income groups, and between all the income groups to a point of complete equality of income between the groups.

The latter part of the chapter consists of enumerating the sources of the data, and the subsequent manipulations of the raw data necessary to fit the requirement of the model. Most of the original data is obtained from the Technical Appendix to the Fifth Plan, published by the Government of India. Several tables are also adapted from Eckaus and Parikh's work. Figures relating to the current distribution of income for use in the reference solution are obtained from NCAER (National Council of Applied Economic Research) publications.

Chapter 5 consists of a detailed study of the results obtained in

the models and suggests policy measures based on them. Initially, a comparison is made of the values of the objective functions obtained under the different redistribution schemes which are feasible. Redistribution between the lower two groups generally leads to higher values of the objective function than redistribution between the upper two groups. Rural redistribution schemes yield higher values than urban redistribution schemes. Agriculture generally has low shadow prices throughout the plan. Consumer goods and services typically have high shadow prices, especially in the first two years.

Redistribution between the two lower groups is feasible in the rural and urban sectors. This holds true if we assume that households retain their old pattern of consumption after moving to a new income group or if we alternatively assume that they instantaneously change their consumption pattern and take on that of the new group to which they belong.

Redistribution between the two upper income groups is feasible in the rural and urban sectors separately, but infeasible when the schemes are simultaneously applied in the two sectors. If consumption patterns are allowed to instantaneously adjust in response to income changes, rural redistribution becomes infeasible.

Equalizing the average incomes between the urban and rural sectors is feasible, and results in a higher value of the objective function than that obtained for the reference solution. In this exercise the distribution of income within each sector is maintained at the status quo.

The sensitivity test results are then considered. The solutions are extremely insensitive to changes in the discount rate. The solutions

are completely insensitive to a change in the discount rate from 10% to 5%. They are fairly insensitive to changes in the discount rate to 20%.

The posing of even moderate post-terminal growth rates lead to infeasibilities in the majority of cases, including the reference solution. The highest post-terminal growth rate possible for the reference solution is 0.3% per annum. Redistribution of income within the rural sector allows higher post-terminal growth rates to be attainable. A redistribution between the upper and middle income groups allows a growth rate of 3.4% per annum, and that between the lower and middle groups allows a maximum possible post-terminal growth rate of 2.5% per annum.

The availability of less foreign aid makes redistribution between the upper two groups less attractive. This kind of redistribution is expected to impose a heavier burden on foreign exchange than other kinds of redistribution, and so the result noted is expected.

A higher savings rate allows us to obtain feasibility for a completely egalitarian distribution. The ranking of the various redistribution schemes based on the value of their respective objective functions is basically the same as that obtained in our initial run.

Several policy recommendations have been made based on the results obtained. The redistribution of rural incomes is obviously very desirable and perhaps necessary to obtain meaningful post-terminal growth rates. It is suggested that by subsidizing the rural middle class on the condition that higher wages are paid by them to the lower class, one can build up a strong rural 'middle-lower' income group, which can act as a counter to the politically powerful rural upper class. This is necessary for effec-

tive legislation to be passed, enabling the implementation of income redistribution schemes affecting the rural upper class. This scheme would not only allow higher post-terminal growth rates to be possible, but also better the economic conditions of the rural lower class, which is desirable on its own grounds.

Finally, there is also a brief discussion about the type of planning into which we must enter to put into effect these redistribution policies. Total quantity planning may be used to obtain the gross outputs recommended in the solution exercises conducted. However, we would expect our results regarding the effects of various redistribution schemes to hold even if partial quantity planning is undertaken, as in the Indian case.

Chapter 6 provides a summary of the results, and the conclusions that may be drawn from them.

We move on now to a study of the meaining of underdevelopment and why its existence makes planning desirable.

CHAPTER 2

DEVELOPMENT, PLANNING AND INDIA

(1) Development

The startling technological breakthroughs that have been experienced by several countries during the last fifty years or so have been usually followed by a tremendous acceleration in the rate of economic growth in these same places. This phenomenon has brought into existence a group of countries which have been characterized as 'developed'. Simultaneously we have been aware of another group, heterogeneous in nature, often widely separated from each other in culture, traditions, and environment which have been branded as 'underdeveloped' — the other side of the coin, as it were.

Although a laborious digression into the world of semantics would be particularly unfruitful at this present juncture, it would be helpful to us to examine the several key senses in which the word 'development' is used. It could, firstly, refer to the 'quality of life', this phrase itself perhaps needing further explanation. More specifically it could relate to per capita incomes or consumption, the level of employment enjoyed by the people, the extent of social overhead capital in existence, the depth of the capital base in the economy, or very many other similar things. More often than not, underdevelopment has also been associated with ignorance, social backwardness and an incapacity to absorb and assimilate new

ideas and techniques. Thus we can enumerate several characteristics of underdeveloped economies which can be used as checks to identify underdeveloped countries. These characteristics very often occur together and even reinforce one another. However, they sometimes do not, and one has to then be very careful in specifying what one means when talking about underdevelopment.

When analysing India's condition, I shall, for operational purposes, distinguish between the two groups of characteristics listed in the previous paragraph. The lack of high levels of income, employment, etc. (the first group), shall be associated with the word 'poverty'. The presence of ignorance and the inability to assimilate new ideas and techniques would imply the existence of underdevelopment. Using these specialised definitions, we could say that, after twenty-five years of national planning, India is still an extremely poor country with very slow progress being made on that front. At the same time, however, India is developing at a fairly fast rate in various fields (such as the production of steel, chemicals, etc.), although even here the development has not been as rapid as planned.

Concurrent with the development process, there has been a great deal of activity on the part of economists and model-builders who have enthusiastically entered the field to try to help in the planning process. For an excellent survey of the work done, both theoretical and empirical, on the Indian economy, the reader is referred to Bhagwati and Chakravarty's article (8). Most of the work, however, seems to be concentrated around the 'development' aspects of planning with attention being paid only tan-

gentially to the problem of stark poverty. The preponderance of efforts alloted to studying the dynamics of change of various economic variables resulted in attention being diverted from the consideration of the absolute levels of some variables which determine the extent of poverty present. These latter represent, in a sense, the 'state of the economy', and as we shall soon see, provide the stumbling blocks on which the well-laid plans of many model-builders go awry. In terms of the programming models which we shall consider later, they give rise to additional boundary conditions which often change the nature of the optimal solution, and may even succeed in making many solutions infeasible. This problem is of a very serious nature. Most programming models that have been developed do not take into account the boundary conditions that are imposed by poverty. While this is acceptable when the models are built for economies in which stark poverty does not exist, in the case of India it imposes a severe limitation on the acceptability of the programming models as guides to practical policymaking. We shall make an attempt to rectify this, and see whether the standard results are substantially altered because of it.

The above also highlights the often-made point that in economic planning, as in the way of life itself, one should be careful in transplanting institutions, laws, codes, etc. from environments which are very different to one's own, merely because they had been successful at the former place. The Bible spoke of old wine in new bottles a long time ago, and Mao Tse Tung has echoed similar feelings in his thoughts. On the contrary, however, the existence of a well-defined rich pool of knowledge is a great asset to the model-builder, even when he is dealing with an

economy which is different from the ones considered before. The adaptation of old models to meet the requirements of changed circumstances is probably easier than building fresh ones from scratch, and on a priori grounds, potentially no less fruitful. The heating system in an automobile may be superfluous in most parts of India, but surely the car is not. The keynote is therefore to have a system which is different not for the sake of being different, but rather so as to make adjustments for the new situation which is being considered.

This can perhaps be better understood if we formulate the problem in terms of simple control theory. We are studying a very simple hypothetical system. The system might be a space vehicle or an economy. We postulate that there are a finite number of variables at each point in time called state variables. Let these be denoted by $x_1(t)$, $x_2(t)$, ... $x_n(t)$. In the case of an economy, these might correspond to different stocks of capital goods at a particular point of time, or perhaps per capita consumption of different commodities at that point. They are called state variables since they symbolize the state of the system, e.g., the state of the economy. Thus, if we are interested in poverty, the state variables would probably represent per capita consumption of various commodities. There are, in addition, several control variables, c_1, c_2, ... c_m, which, once specified for all time, completely determine the path of the state variables for all time. The dependence of the state variables on the control variables can be defined by a set of first order differential equations:

$$(1)\quad \dot{x}_i = f_i(t, x, c), \quad i = 1, 2, \ldots n;$$

where $\dot{x}_i = \frac{dx_i}{dt}$.

In addition, the actual values of the control variables must be from within the feasible set for the control variables, C.

(2) $c \in C$.

The optimal control problem can be stated as:

$$\max \text{ or } \min J = \int_a^b F(x, c)dt;$$

where x, c are vectors and F gives their instantaneous contribution to the objective function, subject to (1) and (2).

We find therefore that the optimal solution depends on the function F, and the value of this function depends solely on the absolute values of the state and control variables. A realistic planning model must therefore pay a great deal of attention to the formulation of a realistic objective function.

In this formulation, it must be remembered that it is the state variable which enters as an argument in the function, and not changes in it. The importance of the state variables vis-a-vis each other therefore have to be determined before a plausible model can be formulated. If some of the state variables are more important than others, this should be reflected in the structure of the objective function, or possibly worked in through the constraints system.

In passing we could note the similarities between this control theory model and Tinbergen's (75) classic analysis of economic policy, by considering aims, targets and instruments. In this case, the target is a flexible one — that of optimizing J whereas the instruments correspond to

the control variables. This similarity is to be expected as the control theory formulation is the most general method of posing an optimization problem in planning.

(2) Planning

The introduction of terms like aims and targets bring in with them the notion of consistency. We have to consider consistency between various aims, and between aims and instruments. In non-technical terms, different aims are consistent with each other if the attainment of some of them do not preclude the attainment of others. Thus, the attainment of a sufficiently high level of employment may clash with the aim of maintaining a price freeze, and just as in the proverbial case of eating a cake and having it too, a choice has to be made. It is this introduction of the choice element, implying certain degrees of freedom being available, which is the essence of planning. Both economic analysis and economic planning give rise to choice. However, planning implies a process which works in reverse to that of analysis. In planning the targets are specified and suitable instruments are chosen. In economic analysis, however, the instruments are specified, and the effects of their operation on target variables worked through.

At this stage, we can formally define consistency models and optimization models.

Consistency model: This framework has as its major objective the maintenance of intertemporal and intersectoral consistency as the plan

moves from its beginning to its end over the planning period, satisfying specified intermediate requirements.

Optimization model: This type of model attempts to single out the best among all alternative consistent plans.

Thus, any set of values satisfying the constraints of a programming problem would satisfy the consistency requirement. However, there may be more than one set of values which satisfy these constraints. It is then that one is faced with the problem of choice, and the need for planning arises. An economy which has only one unique vector satisfying the constraints does not require a planning authority as its choice has already been made.

We now turn to a brief consideration of the history of planning in India.

(3) India

This section is based mainly on the works of R. C. Dutt (27), D. R. Gadgil (30), W. Malenbaum (54), and D. Bhattacharyya (9), V. Anstey (2), and A. Ghosh (32).

(a) Structure of the Pre-Plan Indian Economy.

The Indian economy had been practically stagnant in the first half of the present century. The bulk of the population (about 75%) were in the agricultural sector, which together with fishing and forestry contributed to more than 50% of the national income in the last pre-plan year (1950-51). In that year, factories contributed about 6.5% and cottage

industries and handicrafts 9.6% of the national output. Most of the income was earned in small-scale enterprises. Of the portion of national income which could be classified according to the size of enterprises, we find that 86% of the income was earned in small-scale enterprises. Labour productivity was extremely low, amounting to Rs 665 per annum per worker as an average for the nation. If we consider the fact that there were 1.5 non-workers for every member of the working force we obtain a per capita income per annum of Rs. 260, which at the exchange rate prevailing amounted to $55.

Savings and investment were both very low, amounting to 5% of the national income. Not only was this a constraint put on the expansion of investment activity, but the "ability to invest" (Hirschman (41)) was also low. This term signifies the potential that a country has to invest in the form of skilled workers, innovating and risk-taking entrepreneurs, and in the proper organisation for planning and administering development schemes.

This, of course, is typical of any country which has been subservient to a colonial power for any length of time. If the key to official policy is the extraction of all surplus from a country for the enrichment of another, scarcely any attention will be paid towards the balanced structural development of the former. This is evident in the pattern of development which took place during the last hundred years of British rule. A fairly advanced system of railway communications was set up, as also roadways. However, the pattern of development of transport and communications was geared towards the extraction of raw materials and other prim-

ary products from the economy for transport to the West, and the distribution of cheap factory produce (e.g., cotton textiles) from British factories to the vast markets within the country. Thus, we find that most of the railroads connected the hinterland with the important ports, but the development of transportation between different areas within the country was very limited.

This use of India as a source of raw materials and market for factory products was also reflected in the commercial policies followed. Thus we find that heavy excise duties were clamped on Indian cotton textiles to facilitate imports from the mills in Lancashire.

The plantations were developed too with a view to providing cheap raw materials. Indigo, jute and tea plantations come foremost to mind. The labour used in these plantations was recruited, often forcibly, by contractors. The living and working conditions of the plantation labourers were wretched, even when compared to the impoverished conditions of the working force as a whole.

In the above context, we may consider what Lange (47) had to say about the structure of under-developed economies, whether under a foreign colonial power, or a domestic monarchy:

> "The feudal mode of production is characterised by low productivity and correspondingly a low economic surplus is produced. The feudal ruling class, however, use the small surplus produced for conspicuous consumption, i.e., for unproductive purposes.... instead of utilizing their incomes for capital accumulation and consequent productive employment of labour. As a major part of the underdeveloped countries became subject to colonial rule, this drain of the small economic surplus was increased by the very expensive colonial administration. When an underdeveloped country remained independent, the same drain was usually performed by the

> domestic monarchy and its officials. In the period of monopoly capitalism which started towards the end of the nineteenth century, the unproductive drain of the economic surplus of the underdeveloped countries is reinforced through profit-taking by foreign capital.... The monopoly profits made in this way are on the whole not reinvested in a way conducive to the economic progress of the underdeveloped countries. A major part of the profit of foreign capital is taken out from the underdeveloped countries and used for the economic development of the metropolitan countries ... or are invested in such ways as not to create competition for the basic industries owned by the same monopolistic groups in the metropolitan countries. As these are — as a rule — heavy industries, such capital as is reinvested in the underdeveloped countries is invested in consumers' goods industries and in the production of raw materials and staple food products."

The above quotation from Oskar Lange, reflects very accurately the Indian experience. As she stood on the threshold of the planning era, India had an economy which was characterised by low production, low per capita income, a preponderance of people in the stagnant rural sector, low levels of savings and investment, low productivity, very little technical, entrepreneurial, and organizational talent, a structure of transport and communications which was geared more towards the extraction of raw materials for shipment out of the country than for the balanced growth of output, and an almost non-existent infrastructure of basic industries. After nearly 25 years of planning, most of the problems still exist, but progress has been made on all these fronts with varying degrees of success. Although none of the developments have been of a dramatic nature, the levels of output, employment, savings and investment have risen considerably, and a start has been made towards establishing the infrastructure of basic industries, so vital to a country striving to break away from dependence on others.

(b) Rationale for planning in India

In order to view this subject analytically, let us consider the characteristic features of a planned policy. According to Tinbergen (75), they are "(i) Estimation of future developments as a basis for policy decisions instead of relying on the past evidence available at the moment of decision. (ii) The explicit formulation of more general aims of policy, in the ideal case for the economy as a whole, instead of incidental action. (iii) Coordinated action instead of random action by individual ministries or services."

From the above, we can argue that the need for central planning is greater, the greater the need for these three characteristics in the functioning of the economy. Let us look at this in more detail.

The need for accurate forecasts is greater, the greater the instability present in the economy. In the case of India, the uncertainty surrounding agricultural production due to its dependence on climatic factors, causes instability. This factor seems all the more important when we consider the overwhelming importance of agriculture in the Indian economy.

Consider the second of the three characteristics enumerated above. We can say that the need for planned economic development is greater, the greater the divergence between the aims of a country and its actual performance. This divergence is expected to be great in affluent countries in times of stress, e.g., depressions, world wars, and in poor countries at all times. In the latter, the aim of accelerated development by means of large investments in capital goods is foiled by the inability to gen-

erate a surplus after consumption. In such a case, one has to resort to planning in order to generate and use the surplus.

Finally, the need for coordination is greater, the greater the number of instruments used in the policy. The number of instruments used in turn are greater, the greater the divergence between aims and reality. The exact number of instruments to be used varies with the political and economic philosophy prevailing in the country in question. So we find that communist countries have more targets (e.g., the equalization of income), than the capitalist countries, and have to use more instruments to achieve them. Moreover, the size of a country also determines the amount of effort that has to be spent on coordination. There is hardly any doubt that size-wise, India has one of the larger economies in the world, and this too supports an Indian embarkation on planned development.

We have thus come to the conclusion that accelerated capital accumulation, directed by a central planning authority, is the only course to follow. Broadly the same conclusion was reached by Lange (47) when he said:

> "A characteristic feature of the underdeveloped countries is the lack of a sufficiently broad and wealthy class of domestic industrial capitalists which would command the resources for substantial investments in industrial development. It is impossible to repeat the way taken in the beginning of the nineteenth century by the countries of Western Europe where capital accumulation was carried out with the private resources of the industrial middle-class. In Western Europe this process was also supplemented by resources derived from colonial exploitation. Even under these favourable circumstances, the process of industrial development was relatively slow, too slow to satisfy the social needs of modern times. Neither is industrialization and economic development possible through the influx

> of foreign capital. Foreign capital, on the whole, is ready to come to the underdeveloped countries only as monopoly capital under colonial or semi-colonial conditions.... However, under certain favourable conditions, as in the case of a large and strong country like India, with strong rivalries among different groups of foreign monopoly capital and with economic aid from non-capitalist countries, foreign capital may be utilized to a certain extent for economic development. The extent to which this can be done is, however, strictly limited. For the very conditions of such an advantageous utilization of foreign capital require development of the internal resources of the country in order to make it sufficiently independent and strong to accept foreign capital on its own terms. Under the circumstances stated, economic development can take place only on the basis of public investment...."

We have thus far argued that public investment is necessary for accelerated development. The question of the extent to which public investment should replace private capital formation has, however, been a controversial one. Should the state take over responsibility for all kinds of capital formation or should it merely control several key industries in order to lead the economy? This is an issue which cannot be settled on economic considerations alone. One has to also consider the administrative expenses which the two schemes would involve. By and large, it seems that India is following the latter path of government control over the key or basic industries, while allowing the private sector to operate in the rest of the economy.

(c) The plans

A book published by M. Visvesvaraya in 1934, Planned Economy For India, was the first formal attempt made at setting up a plan for development in India. In 1937, the Indian National Congress set up a National

Planning Committee.

In 1943, two plans were published — the Bombay Plan, drawn up by eight leading industrialists, and a People's Plan drawn up by M. N. Roy. The Bombay Plan aimed at raising agricultural and industrial productions by 130% and 500% respectively over a 15-year period. Per capita income was to rise by 100%, and priorities were to be given to basic industries. The People's Plan gave top priority to agriculture and the consumer goods industries. Its duration was 10 years. A Gandhian plan was also brought out which wanted a decentralized system based on self-sufficient villages.

India attained independence in 1947, and a Planning Commission was set up in March, 1950, after several short-term plans had been put into operation to restore normalcy following the chaotic conditions of post-independence India. The first five-year plan was officially put into operation in April, 1951, and was followed by others.

THE PERSPECTIVE PLAN: 1951-1976

Aims: The plans aimed at a continuous rise in real income, with real investment rising faster than the former. This would be brought about by a substantial increase in the savings rate by having a marginal savings rate far higher than the average. At the outset, deficiencies in domestic resources would be met by imports from abroad, but the deepening of the capital base would soon make the country self-reliant. As the savings rate stabilized at a high value, the growth rate of the economy would be high enough to sustain a continuous increase in per capita income.

Targets: "In this 25-year period, total net investment in rupees of constant value would increase from Rs. 450 crores* in the last pre-plan year, 1950-51, eventually to reach Rs. 5,000 crores in 1975-76, the final year of the fifth plan. From some 5% in 1950-51, as indicated in early plan documents, investment ratios were to grow to 17%. New investment per unit of additional income was scheduled to be almost twice as high in the fifth plan as in the first. This marked increase in capital intensity would be particularly manifest in the modern industry sector,... Nothwithstanding such intensive capital rise, the level of real national income was still expected to be more than three times as high in the last year of the fifth plan as it was in the last pre-plan year. On a per capita basis, real income would more than double over this 25-year period; it was to continue to grow thereafter. The whole development scheme was characterized by an expanding ratio of investment in the public sector to total investment." (Malenbaum (54))

Instruments: "From well under half in 1948-51, and this mostly in infrastructure like railways, power and education, the relative importance of government in new investment was to grow. It was projected at 64% of total new investment in the 1966 draft fourth plan. What is more, along with continued expansion in the basic fields of communications, power and irrigation, government was moving rapidly into direct investment in business enterprises -- machine tools, telephones, paper, steel, chemicals, fertilizer, minerals, and a wide variety of heavy mechanical and electrical machinery." (Malenbaum (54))

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* 1 crore = 10 million; 1 lakh = 100,000.

FIRST FIVE YEAR PLAN: 1951-56

Aims: The main preoccupation of the first plan was with curbing the prevailing inflationary situation and alleviating food shortages. It also tried to increase productivity and set into motion new social and economic processes which would raise the standard of living of the people.

Targets: The first plan envisaged an increase of national income by 11.5% over the period of the plan. This was to be composed of increases in agriculture (by 14%), mining and manufacturing (18%), trade (6.8%), and services (3.2%).

Instruments: "As far as is known the first Five-Year Plan started merely as a process of summarizing, rationalizing and coordinating separate schemes of development and presenting them together, a compilation of the piecemeal projects of the departments, lacking in any theoretical underpinning or overall visualization of the future." (Ghosh (32)) "Of the total public development expenditure, 15% was spent on agriculture and community development, 16% on multipurpose and other irrigation projects, 27% on transport and communications, 13% on power projects and only 6% on industries and mining, including about 2% on the small industries." (Bhattacharyya (9))

Results: Favourable monsoons, unused capacity in industries, and modest targets enabled the country to reach most of its targets. Optimistic Indian planners now prepared for the second plan.

SECOND FIVE YEAR PLAN: 1956-61

Aims: "The pattern of public development expenditure in the Second

Five Year Plan was governed by a different system of priorities. By the end of the First Plan, the food position had considerably improved and the supply of raw materials to industries was also more smooth. The percentage of utilisation of capacity was higher in almost all established industries and the railways were over-worked. The necessity was therefore felt for an all-round expansion in capacity involving initially an expansion in the capacity of the heavy and basic industries like iron and steel, coal, cement, fertilisers, heavy engineering and the heavy chemicals." (Bhattacharyya (9))

Targets: National income was expected to increase by 25% over the plan. This was to consist of sectoral increases of 18% in agriculture, 46% in mining and manufacturing, 23% in trade and 23% in services.

Instruments: "This was very much in advance of the First Plan. In a way, real planning in the sense of a formal projection on the basis of certain sets of assumptions about the economy and its working, was started with the Second Five Year Plan." (Ghosh (32)) The theoretical underpinning of the plan was supplied by the Mahalanobis model. The Second Plan allotted 11.8% of its total expenditure for agriculture, 10% for irrigation and flood control, 18.5% for industries and minerals, 28.9% for transport and communications, 8.9% for power development, and 19.7% for education, health, social welfare and rehabilitation.

Results: The achievements of the Second Plan were far below expectations. National income increased 19%, agricultural production 16% and industrial production by 39%. Meanwhile, a foreign exchange crisis developed. Among the achievements of the plan was a substantial stepping

up of the tax effort.

THE THIRD FIVE YEAR PLAN: 1961-66

Aims: The Third Plan took into account some of the shortcomings of the Second Plan. It restored to some extent the importance of the agricultural sector. The creation of employment opportunities and the provision of facilities for education was also given more emphasis than had hitherto been the case.

Targets: National income was expected to rise by 31%, agriculture by 28%, industrial production by 59%, trade and commerce by 33%, and services by 28%.

Instruments: The plan alloted 14.2% of total public expenditure to agriculture, 8.7% to irrigation, 13.5% to power, 3.5% to village and small industries, 20.3% to organised industry, 19.8% to transport and 17.3% to social services.

Results: "The achievements of the Third Plan were far short of the targets. Again, there was a foreign exchange crises, and the capital-output ratios and investment lags were higher than assumed.... In general, it has been assumed in assessments of the Plan that the targets were originally based on realistic estimates of prospects and parameters. The reasons given for lack of success include not only unforseeable exigencies of weather and increased defense spending, but also inadequacies in implementation which may mean either too little, too much, or the wrong kind of government intervention, depending on the source of criticism." (Eckaus and Parikh (28))

Because of the very disappointing results obtained from the third plan, it was decided in 1966 to postpone the commencement of the fourth plan, so that the planners could make a thorough evaluation of the situation, and modify their plans accordingly. For the three years following the third plan, annual plans were formulated. The following table is a summary of the growth of national income in those years, as also their breakup into the income growths experienced in the agricultural, and mining and large scale sectors respectively.

Indices of Income

Indices of	1960 -61	1964 -65	1965 -66	1966 -67	1967 -68	1968 -69
Total national income	100.0	119.8	113.1	114.0	124.2	126.5
Income in agricultural sector	100.0	110.2	94.1	94.0	110.8	109.6
Income in mining and large-scale manufacturing	100.0	141.8	145.8	147.5	146.3	155.0

Source: Fourth Five Year Plan.

FOURTH FIVE YEAR PLAN: 1969-74

Aims: A major objective of the plan was to create more employment opportunities in the rural and urban sectors. There was also a distinctive aim of attaining a national minimum in standards of consumption.

Targets: National income was expected to grow 31% during the plan. Per capita income was expected to increase 3% per annum. The rate of domestic savings had to be increased from 8.8% in 1968-69 to 13.2% at the end of the plan, and investment increased from 11.3% in 1968-69 to 14.5% by

the end of the plan.

Instruments: The total public sector outlay was Rs. 15,902.2 crores. The breakup was as follows: agriculture and allied sectors — Rs. 2,278.2 crores (17.2%); irrigation and power — Rs. 3,534.1 crores (21.1%); industry and minerals — Rs. 3,337.7 crores (21%); and transport and communications — Rs. 3,237.3 crores (20.5%).

(d) Critique

India has had nearly twenty-five years of planning. The long-term objectives of the plans, when they were first formulated, were set in a twenty-five year perspective. Now that that length of time has nearly elapsed, we find that in a great many respects expectations have not been realised, and targets not fulfilled. Only the first plan could be called considerably successful. All the other plans gave rise to serious deficiencies, and sometimes crisis situations existed, e.g., the foreign exchange crisis during the second plan, and recurrent food shortages whenever climatic factors were not favourable.

Excepting for the first one, the plans have generally been formulated on the basis of macro economic models, and formal tests for consistency conducted. The basic strategy has been usually clearly outlined, and the actual outlays correspond very closely to figures obtained in exercises with the mathematical models on which they are based. Actual targets have been revised if they were found to be too optimistic or too pessimistic. The achievements have, in most cases, fulfilled targets partially. The aim of building viable basic industries is being slowly

achieved, but, somehow, the results obtained do not seem to be good enough. Thus, even though each of the plans could be called a partial success, the cumulation of partial failures over the years have generated what has been called a "quiet crisis in India".

The summaries of the various plans give us an idea of the format on which they are based. A thorough evaluation of them is difficult because the models on which they are based are not available to the public. Thus, we do know that tests are carried out to ensure inter-sectoral consistency, but the assumptions and relationships used to derive final demand and investment figures are not clearly spelled out. When we do observe deficiencies and bottlenecks, a lot of guesswork is involved in trying to determine what went wrong.

One criticism, which has been frequently levelled against the planning authority, is that, although great care is taken to ensure inter-sectoral consistency, not much attention is paid to inter-temporal consistency. Bergson and Manne (6) found the fourth plan to be inter-temporally almost consistent. This meant that proper attention was not given to the time phasing of projects. So, we could have had a situation where machinery was bought to start a factory but the factory itself was not built! Sometimes these bottlenecks could work in a vicious circle. The solution, of course, is to take into account inter-temporal consistency when a plan is made.

Another general criticism levelled against the plans is that they have been too aggregative. Proper attention has not been paid to the various sectors which exist within the broad aggregate. A more decentral-

ised system of planning could solve this problem. In this respect, the Indian plans have not really followed the example set by their Soviet predecessors. In the Soviet planning system, a two-way communication system existed between the planners at the top, and those who operated at the local level. There existed a hierarchical system which linked the planners at the different levels. Broad plans and development strategies were worked out at the top, and were transmitted through the various levels of planners until they reached the bottom. Messages from the local level were then sent back to the top. Kornai (45) gives a very vivid description of this process. He also presents algorithms to solve programming problems which arise in what he calls "two-level planning". Thus, a coordinated system of planning results. In the Indian case, however, there has hardly been any participation by the lower echelons in the planning process. Village councils have been set up, and a huge agricultural and community development scheme started with their base in the village. However, in most cases, participation has been very weak. Decision-making at the lower levels to fulfil plan targets have been almost negligible. The planning apparatus in India looks like a topheavy structure with sweeping decisions being taken at the higher levels without any machinery being created to translate them into tasks to be performed by the lower ranks.

A point related to the above is that the plans affect only a very small section of the economy. The actual plans themselves are programmes of expenditure to be undertaken by the public sector in different areas of the economy. Sometimes figures for private investment are also given, but no detailed breakup by sectors is given. There is no indication as to who

is supposed to undertake these expenditures, nor how he is expected to raise funds for them. The major section of the economy is unorganised, and is affected very little by plan expenditures. The plan work should now be devoted to ensuring that the lead taken by the public sector is followed by theother parts of the economy, through linkage effect. Key sectors have to be identified (68), and the government should control them directly so that the effects can seep through to the rest of the economy. At present, a dual economy persists with a modern organised sector which is making tolerable improvements under the plans, and a stagnant rural sector, which is still backward and very much unaffected by what happens in the plans.

The technique of raising resources for the plans has also been called into serious question. The technique used has been one of calculating the savings forthcoming domestically, and bridging the gap between it and the investment by various ad hoc means (such as the printing of new money). One wonders whether this is the right way to decide on one's outlay. As A. K. Dasgupta (24) put it,

> "One is reminded here of the textbook distinction between private finance and public finance to the effect that whereas in the former, expenditure is adjusted to income, in the latter, income is adjusted to expenditures. Planning is, if anything, an extension of the area of public finance.... In planning, as much as in public finance, expenditure — which in the context of development is what we call investment — has a prior claim for consideration, to be fixed with reference to some sort of a target; resources are then to be adjusted to it, even though the determination of the target itself may have to be based on an estimate of the range of possibilities of resource mobilization."

Concern regarding the savings ratio has led to lower targeted

growth rates than could be achieved, and actually have been achieved by other countries at a similar stage in their development. One must not, of course, overdo the argument, or underestimate the importance of having an adequate domestic savings rate. Once a pattern of investment is formulated, the supply of savings for it is certainly not automatic. However, it could be obtained by suitable financial policies in a country like India, which has one of the most unequal distributions of income in the world. "In India ... the really problematical issues for development are certain specific needed inputs of commodities, skills, organization, and foreign exchange. The appropriate strategy is one that is geared to these specific scarcities." (Lewis (51)). So, as Hirschman (41) has pointed out, the"ability to invest" may place a closer limit on capital formation in underdeveloped ountries than the "ability to save".

Foreign exchange poses one of the crucial bottlenecks for the economy. When analyzing this problem, too, we cannot take the "required savings approach". The statement that we do not save enough to pay for all our investments, and therefore borrow from abroad, is not a correct formulation of the problem. We could, alternatively, say that the foreign exchange bottleneck, by limiting investment, restricts the growth of national income, and thus prevents adequate savings from being made available.

Since most of India's imports are necessary for her development plans (there being stringent restrictions on non-essential im-

ports), it will be very difficult to economise on them. Her export prospects are not very bright either. The demands for her traditional exports, e.g., jute and tea, are sluggish, and raw materials have very unstable markets. Decisive action has therefore to be taken to start a balanced growth process to enable her to supply her necessities domestically. This requires action on a broad front so that individual demands and supplies can be matched. And this is exactly where the plans have failed. The plans have merely concentrated attention on certain selected areas of the economy, without paying proper heed to whether their effects seep through to the rest of the economy. Unbalanced growth has been the order of the day.

It is usual to talk about the first plan as being agriculture-oriented, the second being industry-oriented, and the third, while being still industry-oriented, shifting its emphasis slightly to agriculture. When taken in conjunction with the usual plan tables showing the percentages of total public outlay to be devoted to agriculture, industry, etc., we tend to think of the two sectors as being competitive. This, however, is not the case. The main constraint on industrial growth is a shortage of capital which can be interpreted as a shortage of foreign exchange. However, the prime constraint in the agricultural sector is the lack of suitable organization. These constraints are unrelated to each other, at least, in any simple way. Thus it is possible to press on with the growth of heavy Industry and agriculture simultaneously withou contradictions arising

in the system.

An important lacuna in the plans has been the complete neglect of policies geared to influencing the distribution of income. This is rather strange as its importance is acknowledged by people from all walks of life, and by the planners themselves in the draft outline of the fifth plan. Greater attention ought to be paid to this area of the plans.

Considering the plans in turn, we find that not much is written or said about the first plan. This may be because in many senses it was not a plan at all. If a plan may be defined as a coordinated and consistent series of measures, we find that the first five year plan does not fit into the category. It was rather an enumeration of schemes and projects already in existence, and an estimation of the levels of performance which could be reached by these at the end of five years. The first plan has been called an agricultural plan, but that merely reflected thepattern of investment in various projects which were already in existence within the economy.

The first plan has also been called a moderately successful plan. That, however, was due to favorable weather conditions in the agricultural sector and unused capacity which existed in the manufacturing sector before the plan.

India began planning in a meaningful sense only from the second plan onward. The Mahalanobis model (53) was used in this plan for, firstly, allocating investment between the investment and consump-

tion goods sectors, and secondly, allocating investment among the various consumer goods sectors with a view to creating a certain targeted level of employment. The plan followed Mahalanobis' figures very closely and gave a lot of emphasis to the capital goods sector. The model, however, was too aggregative, and did not pay enough attention to internal consistency. As a result of this, serious bottlenecks developed, and the plan performance was rather disappointing.

Unfavorable monsoons worsened the situation. The estimates of population growth (1.25% per annum) were found to be too low, the actual growth rates being nearly double that figure. The latter was due to a sharp reduction in death rates, because of improved medical facilities, with no corresponding reduction in birth rates.

In the application of the Mahalanobis model itself, there were grave discrepancies in the estimates of the savings rate and the capital-output ratios. As pointed out by Ghosh (32), the savings rate estimate was too high and the capital-output ratio estimates too low, both errors contributing to overly optimistic forecasts of the growth of national income. The latter was due to the presence of excess capacity in the economy.

The third and the fourth plans seemed to have suffered from the same lack of linkage effects between the fast growing organised sector and the stagnant traditional sector. Growth proceeded in a very lopsided manner. In this connection, one remembers Hirschman's (41) thesis of unbalanced growth, according to which certain key sectors

develop fast, and then backward, forward, and lateral linkage effect pull up the rest of the economy. In this case, certain sectors have been growing at a modest pace, but the rest of the economy does not show very many signs of keeping pace with them.

In summary, we can say that the plans will only be successful if the entire economy can get involved in the development process. It is a tribute to the tolerance of the people that even after 25 years of planning, grave inequalities of income distribution and semi-starvation conditions for about 30% of the people can exist while producing only a "quiet crisis".

CHAPTER 3

OPTIMALITY CRITERIA AND PLANNING MODELS

(1) The Planning Problem Posed

We shall, in this chapter, undertake a critical investigation of the several crucial problems which exist in planning, both theoretical and empirical, and consider the various solutions that have been offered for them. We shall, in the process, make a survey of different types of planning models which exist in the literature, and consider their limitations in the light of the problems that they try to solve. The limitations considered shall include both those which are general in nature and also the ones which specifically limit the applicability of such models to economies like India's.

We can start off by considering a problem which has been an age-old favorite with economists -- that of the Robinson Crusoe economy. Crusoe, marooned on a deserted island, looks around for sustenance. Due to the lack of game and wild life on that island, he thinks that fishing would be a good idea, and fashions a makeshift rod and tackle for that purpose. He finds however that with these implements, the catching of fish is a slowgoing and laborious process. The idea of making a fishing net strikes him. He knows that once the net has been made, his prospective catch would be much higher than what it would be without it. However, during the period of time that he is weaving the net, he would be able to

devote much less time to the catching of fish. Moreover, the more sophisticated that he makes the net, the higher will be his prospective catch, but correspondingly the more time will he have to devote to making it. He thus has to make a choice. By sacrificing varying amounts of present consumption, he can correspondingly add varying amounts to his future consumption. In deciding what is the optimal amount of present and future consumption for him, he solves one of the simplest problems in planning.

This simple model not only illustrates an elementary problem of choice but also shows the importance of the gestation period of investment. The fishing net becomes productive only after a time lag. This is especially important in this case, as Crusoe is obviously planning with a finite time horizon at this stage. The models connected with optimal planning under infinite and finite time horizons shall be briefly considered later.

Let us assume that Crusoe weaves a modest net, catches fish and prospers. After a period of time the wearing away of the net becomes evident. The persistent usage has led to its depreciation. Holes appear in various parts of the net through which some of the fish slip away. It is less efficient. Moreover, his staple fish diet has led to a gradual depletion of the availability of fish in the immediate vicinity of the island. The fishing net cast from the island is becoming less and less efficient in catching fish, and a boat which could take Crusoe away from the shore would definitely improve matters. The old techniques of production are becoming obsolete and require replacement by newer techniques of production which require new equipment.

What then are the alternatives facing Crusoe between which a choice has to be made? He could continue fishing as before until his net wears out. In that way his entire efforts would be devoted towards producing for present consumption. He could make repairs on his net which would represent replacement investment to take care of depreciation. He could weave a new net which would be investment in an old type of capital good. Or he could build a boat which would be investment on a new kind of capital to take account of obsolescence. We find that the alternatives facing Crusoe have increased and his choice mechanism has become more complicated as the economy itself becomes more complicated.

An important point to be noted in the analysis so far is that Crusoe's labour time is the sole limiting factor on production. Natural resources are available in plentiful supply as yet. This is to be expected in an under-populated economy like Crusoe's but need not, and normally will not be the case. We will find later that considerable adjustments have to be made to economic theory and the results obtained from it when the number of limiting factors increase from one.

Man Friday enters the scene and the total availability of labour increases. However, his fish-catching skills have not been overly-developed, and the only way he can fish is by using the old-fashioned rod and tackle. Crusoe now has another choice. He can use his time, i.e., resources, to teach Friday how to use a net. He can use some more of his time to teach Friday how to make a boat and row it out to fish. Downward mobility is assumed between occupations graded according to their levels of sophistication. Thus, if Friday has been taught to construct a boat,

and take it out to sea to fish, he can surely cast his net from the shore. Multi-skill manpower planning has been introduced. A model which is based very much on these rudimentary ideas has been used by Alan Manne in his DINAMICO model of the Mexican economy. A good summary of it appears in Goreux and Manne (57).

As the economy prospers still more, the residents of the island become more ambitious and try to produce more complex commodities like, say, a log cabin. The complexity arises from the fact that they cannot immediately start constructing the cabin. They have to first cut down trees to obtain logs. Thus some kind of saw has to be fashioned. Nails and hammers are required to construct the cabin as also to perhaps make the saw. Thus a pattern of inter-connectedness becomes apparent in the production process. We could say that the lines of production have lengthened. It is no longer a question of merely putting human effort to directly make the desired commodity. Intermediate commodities have to be produced first. Moreover, they still have to catch fish in order to survive. This is a particularly important point to keep in mind when considering many of the poor countries in the world where a large section of the population is waging a fierce battle to merely survive. Of course, since the sole limiting factor is labour, one can still evaluate the worth of each commodity in terms of labour costs. However, the simple production function does not exist any more, and one has to introduce detailed input-output techniques to find out whether the production of a particular commodity is viable. The inter-connectedness and the viability of the production process will be looked at briefly later.

The complexities of production bring in the notion of consistency to planning. If a log cabin of specified dimensions is to be built, a certain minimum number of logs have to be cut down in order to make it possible. Moreover, when planning over a length of time the decisions have to be also inter-temporally consistent. If one wants to complete the cabin by year 'three', one has to have the requisite supply of logs before that time.

The discovery of another inhabited island nearby brings in further alternatives between which choices have to be made. Crusoe may now devote his entire time and resources to making boats, and import his fish requirements from the other island or vice versa. If the other island is technologically more developed and produces outboard motors for boats, Crusoe might consider building motor boats by importing motors. However, since he does not make motors at home, his imports of them will not compete with production at home. If he now decides to get married and set up a family, he has to make a further choice between producing for the present, and producing for the future generation.

We thus find that a multiplicity of choices face even this very simple economy. We know that the actual choices made have to be optimal in some sense. This however is merely stating the problem. Lacking any explicit knowledge of some kind of rule for ranking different levels of social welfare one has the option of terminating the discussion here. This could provide smug contentment to theorists but really does not solve the problem of making a decision. Crusoe and Friday do make a decision and it is up to us to find out the basis on which this is made, as also

to enumerate several sensible criteria on which it could be made.

To begin with, we could assume that the utilities of the different individuals comprising a society should have some relation to total social welfare. This presupposes, of course, that individual utilities are measurable and comparable, and that is assuming a lot. Overlooking this factor however we find that still we run into trouble. Arrow's (3) theorem on the impossibility of obtaining a social decision rule from individual utility functions satisfying some very simple sensible rules is well known, and requires no further elaboration. Intuitively this result is very easily understood. If the tastes of Crusoe and Friday are irreconcilably opposed as regards any particular activity, we cannot say what course of action would be socially optimal.

We therefore bypass this problem in optimal savings and growth theory and assume that the welfare function of society as a whole is given, and is dependent on various aggregative economic variables, usually some measure of consumption. The several optimal savings and growth models that have been built usually differ from each other in the exact nature of the utility function used, the type of production function assumed and the length of the planning horizon considered. Though much water has flowed under the bridge since Ramsey (65) originally posed the problem in 1928, we shall attempt to point out the important results obtained in this field as well as the lessons they hold out for our own work. To this we now turn.

(2) The objective function: optimal time patterns and the utility function

The problem of optimum savings was first considered by Frank Ramsey in the Economic Journal (1928). Interest in the topic lapsed with the advent of the Great Depression and the War, until it was revived by Tinbergen in the 1950s. We shall consider Ramsey's model and one of Tinbergen's earlier models in some detail so as to get some idea regarding the framework within which this problem was tackled. The major points made by other later models will then be stated without the detailed workings being shown.

Ramsey, assuming an infinite time horizon, postulated a general utility function of the form $U(C_t)$, where C_t = consumption at time 't', assumed to increase monotonically with time.

The problem can then be written as:

$$\max \int_0^{\infty} U(C_t)dt \qquad (1)$$

It is evident that the above integral does not converge. To get around this problem, Ramsey introduced the notion of bliss. 'Bliss' was defined as the maximum value that could be assumed by the utility function and was denoted by B. Assuming a monotonically increasing consumption function, therefore:

$$B = \lim_{t \to \infty} U(C_t). \qquad (2)$$

The existence of this bliss level could be explained in two different ways. On the one hand, this could come about through satiation in

consumption. On the other hand, production limitations, because of resource constraints, could determine the bliss level. However, it came about, a particular level of bliss was determined. The above maximum problem could then be looked upon as a minimization problem as follows:

$$\min \int_0^{\infty} [B - U(C_t)]\, dt. \tag{3}$$

The equivalence of the two formulations can be understood better by considering the following diagram:

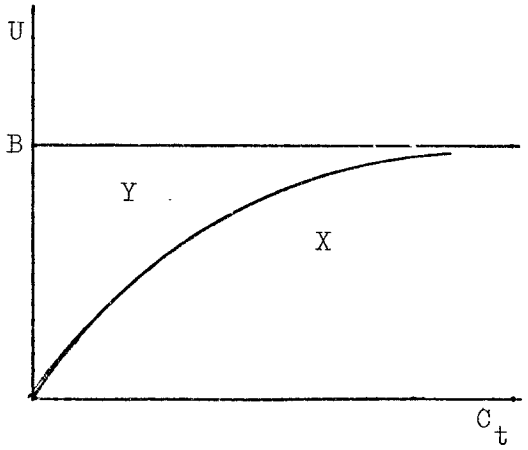

Figure 1

Instead of maximizing area X as under the original formulation, one now minimized the area Y.

Let $Y = F(K)$ be the production function (4)

where Y — total production

K — stock of capital

Now, $Y_t = C_t + S_t$ (5)

$= C_t + \dot{K}_t$, where dots represent derivatives taken with respect to time.

$$\text{or } C_t = Y_t - \dot{K}_t \tag{6}$$

$$= F(K_t) - \dot{K}_t$$

the problem is:

$$\min \int_0^{\infty} [B - U\{F(K_t) - \dot{K}_t\}]dt \tag{7}$$

This is a problem of the calculus of variation, and we shall use certain standard mathematical results which exist in the literature on it.

Mathematical result: A necessary condition for K(t) to give a maximum or minimum for the integral

$$\int_a^b F[t, K(t), \dot{K}(t)]\, dt$$

is that K(t) satisfy the Euler differential equation

$$\frac{\delta F}{\delta K} - \frac{d}{dt}\left(\frac{\partial F}{\partial \dot{K}}\right) = 0$$

Thus in our case the Euler's condition is

$$\frac{\partial U}{\partial K} = \frac{d}{dt}\left(\frac{\partial U}{\partial \dot{K}}\right) \tag{8}$$

$$\text{or } \frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial K} = \frac{d}{dt}\left(\frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial \dot{K}}\right) \tag{9}$$

$$\text{or } U' \cdot F'(K) = -\frac{d}{dt}U' \tag{10}$$

$$\text{Thus: } F'(K) = -\frac{\frac{dU'}{dt}}{U'} \tag{11}$$

Mathematical result: If F does not contain 't' explicitly, then the Euler equation implies $F - \dot{K}\frac{\delta F}{\delta \dot{K}} = \text{constant}$.

Since in our case, 't' is not contained explicitly in the integral,

we can say:

$$U - \dot{K}\frac{\partial U}{\partial \dot{K}} = M \text{ (a constant).} \tag{12}$$

$$\text{or } U - \dot{K}\frac{\partial U}{\partial C} \cdot \frac{\partial C}{\partial \dot{K}} = M \tag{13}$$

$$\text{or } U + \dot{K}U' = M \tag{14}$$

Now at the bliss level,

$$U = B, \text{ and } U' = 0. \tag{15}$$

substituting in the above:

$$B + 0 = M, \text{ or } B = M. \tag{16}$$

Thus:

$$U + \dot{K}U' = B \tag{17}$$

$$\text{or } \dot{K}U' = B - U \tag{18}$$

$$\text{or } \dot{K} = \frac{B - U}{U'}, \quad \dot{K} \text{ is investment.} \tag{19}$$

Thus, the above equation gives us Ramsey's rule for optimum savings with an infinite time horizon.

The criticisms of this model are mostly centred around the notion of bliss. At best, it is a very nebulous concept. Normally in the theory of consumer behaviour, we assume that individual wants are insatiable. Moreover, the continuing search and discovery of new kinds of resources also make it operationally fruitless to estimate the bliss level from the production side. The path-breaking nature of the Ramsey article, focussing as it did on the essential mechanism of the optimizing process, is the key to its importance.

Tinbergen (76) did away with the concept of 'bliss'. He assumed

a utility function which possessed a constant elasticity 'v' above a subsistence level of consumption 'C'. Thus:

$$\frac{dU}{dC} = (C - \bar{c})^{-v}, \quad v > 0. \tag{20}$$

Integrating both sides:

$$\int dU = \int (C - \bar{c})^{-v} dC \tag{21}$$

$$\text{or } U = \frac{(C - \bar{c})^{1-v}}{1 - v} . \tag{22}$$

A fixed coefficients production function was assumed:

$$Y_t = \frac{K_t}{\alpha} \tag{23}$$

Thus the problem was:

$$\max \int_0^{\infty} \frac{(C_t - \bar{c})^{1-v}}{1 - v} dt \tag{24}$$

$$\text{subject to } Y_t = \frac{K_t}{\alpha} \tag{25}$$

Again,

$$C_t = Y_t - \dot{K}_t \tag{26}$$

$$\text{or } C_t = \frac{K_t}{\alpha} - \dot{K}_t \tag{27}$$

$$\text{We max} \int_0^{\infty} \frac{\left(\frac{K_t}{\alpha} - \dot{K}_t - \bar{c}\right)^{1-v}}{1 - v} dt \tag{28}$$

The Euler's equation for a maximum (simplified) is:

$$\dot{C} = \frac{1}{\alpha v}(C - \bar{c}). \tag{29}$$

Solving this we obtain a time path for consumption:

$$C_t = Ae^{\frac{1}{\alpha v}t} + \bar{c}, \quad \text{where A is an arbitrary constant.} \tag{30}$$

Plugging this into (27) above, we obtain a differential equation in K_t. Solving for this, we obtain a time path for K_t. The solution is:

$$K_t = B_1 e^{\frac{1}{\alpha}t} + B_2 e^{\frac{1}{\alpha v}t} + \bar{c} \tag{31}$$

where B_1 is an arbitrary constant and $A = \frac{B_2}{\alpha}(1 - \frac{1}{v})$.

Certain boundary conditions were imposed. These were:

$$K_t \geqslant 0, \text{ and } C_t \geqslant \bar{c}; \tag{32}$$

Now

$$\left.\begin{aligned} K_t \geqslant 0 &\Longrightarrow B_2 \geqslant 0 \\ \text{and } C_t \geqslant \bar{c} &\Longrightarrow B_2 \leqslant 0 \end{aligned}\right\} \quad \text{Assuming } v < 1 \tag{33}$$

Thus

$$B_2 = 0 \tag{34}$$

But this means that consumption would remain at the subsistence level throughout the planning horizon for the optimum savings programme.* The deficiency of this kind of model was apparent to Tinbergen who now reformulated it to rectify this shortcoming. A time discount rate "r" was assumed. The problem then became:

$$\max \int_0^{\infty} e^{-rt} U(C_t)dt \tag{35}$$

$$\text{subject to } Y = \frac{K_t}{\alpha} \tag{36}$$

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* - Intuitively, because consumption at any time period enters the utility function in the same manner, it would be optimal to keep adding to the productive capacity of the economy, and realizing the entire consumption in the last period when maximizing utility.

$$\text{with } U(C_t) = \frac{(C_t - \bar{c})^{1-v}}{1 - v} \quad \text{as usual.} \tag{37}$$

The time path obtained for consumption was:

$$C_t = Ae^{\frac{1}{v}(\frac{1}{\alpha} - r)t} + \bar{c} \tag{38}$$

$$\text{and } K_t = B_1 e^{\frac{1}{\alpha}t} + B_2 e^{\frac{1}{v}(\frac{1}{\alpha} - r)t} + \bar{c} \tag{39}$$

where A, B_1 are arbitrary constants and

$$A = \left[\frac{1}{\alpha} - \frac{1}{v}(\frac{1}{\alpha} - r)\right] B_2. \tag{40}$$

If the discount rate is chosen high enough, the first term in solution (39) will dominate the second. In this case, the imposition of the boundary conditions $K_t \geq 0$, $C_t \geq \bar{c}$ will not necessarily lead to $B_2 = 0$.

A consideration of these models illustrates the difficulties involved in obtaining a truly optimal path over an infinite time horizon based on certain simple assumptions. Tinbergen also suggested the introduction of a finite time period 'T' and marginal utility elasticity of consumption equal to 0 for $C > \bar{c}$ and to infinity for $C < \bar{c}$, i.e., the marginal utility of consumption is constant. In that case, the problem reduces simply to one of maximizing terminal consumption while keeping intermediate consumption just above the subsistence level. As T tends to infinity, intermediate consumption becomes equal to $\bar{c}$. Several linear programming models, e.g., Sandee's (71), seem to be based on this kind of philosophy and have the maximization of terminal consumption as their objective function. This again illustrates how our model-builders tend

to neglect the actual state of the economy during the planning period. In this case, it is done because of the nature of the utility function assumed, about which no reliable estimates can be made. The imposition of a discount factor which is sufficiently high does allow intermediate consumption to be above the subsistence level, but this is rather an arbitrary method of doing so, and creates the problem of deciding what this discount rate should be. Perhaps the problem lies, as Koopmans has said, in assuming that the present generation of individuals have an utility function which holds for all future consumption levels, and this remains constant even when the present generation passes away.

> "... portrayal of preference, technology and population growth ... The formulae by which we have been trying to capture these phenomena bear the marks of their intellectual parentage in the classical immutable laws of the physical sciences. They have no provision for the continual adjustment of preference, knowledge, practice, and custom to new experience and observation. In brief, they lack the flexibility that is an essential trait of all human response to a changing environment." (Koopmans (44))

But this need not necessarily be so, and generally will not be so. A mechanism for the continuous adjustment of the utility function through time may give us consumption paths which will really be optimal and generally appear to be so, too. Otherwise, it has been suggested that we might look at the problem the other way around, start with an optimal consumption path and derive the utility function from it. This is what has perhaps been done by most linear programmers when they experiment with different kinds of objective functions.

The non-convergence of the maximand, which is a principal matter

of concern for infinite horizon planning models led Chakravarty (17) to construct a finite horizon planning model with specified terminal capital stocks. He argued that if the maximand was insensitive to the particular choice of the terminal capital stock, it would tend to justify his using a finite horizon model as a proxy for an infinite horizon one. He did find the maximand to be insensitive to the level of the terminal capital stock. He also found that the value of the maximand was sensitive to the length of the planning period.

Maneschi (56) criticized his model on various counts. Since the maximand was sensitive to the length of the planning period "T", all optimum savings made would be consistent only if the "T" remained the same as time passed. However, if a planner in the future changed this "T", all previous decisions made would be regretted.

He also maintained that the insensitivity of the maximand to the terminal stock, and therefore the growth rate of capital, was due to the particular values of the various parameters chosen. He showed that if more "relevant" values for the parameters were chosen, then the sensitivity increased. His argument for deciding on the "relevance" of these values ran in the following manner. He claimed that if the value of the maximand was not much affected by the choice of the growth rate "g", the population would try to leave as much capital as possible for the future. Thus "g" would be as close to the output-capital ratio "b" as possible. If one conducted sensitivity tests near these ranges, he found their values to be much higher. He also noted that Chakravarty's solution resulted in a massive accumulation of capital during the planning period with rapid decumulation of the same near the end to meet the terminal

stock requirement. This he found to be unrealistic.

Two distinct criticisms are present in the previous paragraph. The rapid decumulation of capital, however, represents the tendency seen in all kinds of optimum savings models to keep postponing consumption to the maximum extent possible, and is not a shortcoming of this particular model alone.

While dwelling on the subject of optimum savings, one must cite the contribution of von Weizsäcker (79) who devised another ingenious means to get around the problem of non-convergence. He defined a particular consumption path C_t^* to be better than another C_t if there existed a T such that

$$\int_0^t u(C_t^*)dt > \int_0^t u(C_t)dt \quad \text{for all } t \geq T. \tag{41}$$

It was proved that if one assumed a constant population and constant technology, a unique optimal path could be obtained for the Ramsey problem.

There were several other models built with differing assumptions yielding different conditions for the existence of an optimal savings path. The utility function was made dependent on per capita consumption by Cass (14), Koopmans (44), and Malinvaud (55). Mirrlees (61) assumed exogenous technological progress of the labour-augmenting type, and Inagaki's (42) model has been built considering exogenous technological progress of the capital-augmenting type. Koopmans (44) built a model in which the discount factor depended upon the prospective level of consumption.

The major problem facing these models is that of an infinite postponement of consumption. This arises if future consumption is made too attractive as compared with the present. In fact, a lot of the devices introduced are meant explicitly to make future consumption seem less desirable.

It is against the background of optimal savings literature that we choose our objective function when actually formulating a planning problem. The constraints of this problem occupy us next.

(3) The Constraints:

The Leontief Static model

The major constraints in any optimization problem are posed by the production relations. These relations are usually shown in an input-output framework. The simplest kind of input-output relationship is written as follows:

$$Ax + f = x \tag{42}$$

where A is an n x n matrix with typical element a_{ij} denoting the quantity of 'i' required to produce one unit of 'j';

x is an n x 1 vector of gross outputs of the commodities; and

f is an n x 1 vector of final demand for the commodities.

A study of the matrix A reveals the pattern of inter-connectedness

which prevails in the economy.

Definition: An n x n matrix A is decomposable if there exists a permutation matrix P such that

$$PAP' = \begin{bmatrix} A_1 & x \\ 0 & A_2 \end{bmatrix} \tag{43}$$

where A_1 and A_2 are square submatrices along the principal diagonal. If there does not exist any such matrix P, it is indecomposable.

Finding out whether the input-output matrix is decomposable is of vital importance in planning. This is because decomposability implies the existence of a hierarchical order of industries, with every industry contributing inputs to industries below it, but not above. In this case, we could get an ordering of industries that would tell us which industries would have to be developed first before others could grow. A major portion of input-output work is concerned with finding out whether this matrix is decomposable.* It is interesting to note that Manne and Rudra found the Indian economy to exhibit what they called 'block-angular characteristics'. They divided the economy broadly into agriculture, manufacturing and universal intermediates. They found the flows connecting agriculture to manufacturing to be negligible. This could provide an explanation of the partial success of industrial development even when agriculture was stagnating.

Interest has also centred around finding out which are the key

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* - The literature sometimes refers to a decomposable matrix as one which can be triangularized.

industries in terms of providing maximum backward and forward linkage effects. Indices have been devised by Rasmussen (68) to measure the importance of various industries in terms of linkage effects. It is interesting to note in the Indian Industrial Policy Resolution that industries were divided into three groups, and the maximum amount of importance was given to a group of "basic" or "core" industries. Some form of analysis based on linkages must have been undertaken to determine them.

Reverting back to equation (42), we find that the simplest form of consistency exercise can be based upon it. Thus we have

$$Ax + f = x \tag{44}$$

$$\text{or } x = (I - A)^{-1}f \tag{45}$$

If a vector f of final demands is specified, we can use the input-output table to find out the gross outputs that it would imply. The literature on input-output (hereafter referred to as I/O) analysis abounds in exercises done on variants of this model. The work of Manne and Rudra (60) on the Indian economy was one of the earlier models of this type. They projected various levels of final demand for 1971 and worked out an internally consistent vector of gross outputs. The use of physical and material balances have been used widely in planning in the Soviet Union and in many East European countries.

Mention must also be made of a partially closed model of the Indian economy constructed by Padma Desai (25). In the model, part of the final demand vector was determined endogenously. This was an improvement, since, in a poor country like India, a basic minimum of consumption to "produce" labor may not be available unless specific

attention is paid to it. Desai's model involved (a) the formulation and implementation of an input-output model for India, closed with respect to all household consumption except that originating from government employees; and (b) an endogenous determination of the distribution of consumption expenditure among several groups of households, each group having a specific consumption pattern.

The Leontief Dynamic model

In the Leontief Dynamic system, different time periods are linked together by the existence of stocks of commodities which are not used up in the production process like the current flow variables, but are passed on from one period to another. The production function therefore changes its character. Whereas formerly it had looked like:

$$x_i = \min \left(\frac{x_{1i}}{a_{1i}}, \frac{x_{2i}}{a_{2i}}, \ldots \frac{x_{ni}}{a_{ni}} \right), \tag{46}$$

now it becomes:

$$x_i = \min \left(\frac{x_{1i}}{a_{1i}}, \frac{x_{2i}}{a_{2i}}, \ldots \frac{x_{ni}}{a_{ni}}, \frac{S_{1i}}{b_{1i}}, \frac{S_{2i}}{b_{2i}}, \ldots \frac{S_{ni}}{b_{ni}} \right) \tag{47}$$

where x_{ij} is the requirement of commodity 'i' as current flow input for producing commodity 'j';

S_{ij} is the requirement of commodity 'i' to be held as as stock for producing commodity 'j';

a_{ij} is the requirement of commodity 'i' as current flow

input for producing one unit of 'j';

b_{ij} is the requirement of commodity 'i' to be held as stock for producing one unit of 'j'.

The demand for stocks S is given by

$$S = Bx \tag{48}$$

where S is an n x 1 vector with typical element $S_i = \sum_j S_{ij}$

and B is an n x n matrix with typical element b_{ij}.

Thus,

$$\dot{S} = B\dot{x}. \tag{49}$$

In writing out the Leontief static system in the form of equation (42), we had assumed that supplies of commodities equalled intermediate and final demand. Now we assume that no excess stocks exist. Our demand and supply balance equation can therefore be written as:

$$x(t) = Ax(t) + B\dot{x}(t) + f(t) \tag{50}$$

$$\text{or } \dot{x}(t) = B^{-1}(I - A)x(t) - B^{-1}f(t) \tag{51}$$

Denoting $B^{-1}(I - A)$ by C, we have:

$$\dot{x}(t) = Cx(t) - B^{-1}f(t). \tag{52}$$

This is a first order differential equation which could be solved. A problem immediately arises if B is singular. There is good reason to expect B to be singular as there are many commodities which do not enter as stock into any production process. This would imply an entire row of B consisting only of zeros. Then we would have to work with a reduced system of equations. However, the normal procedure is to assume that B has full rank. In that case, the model has a solution of the form:

$$x(t) = e^{Ct} \cdot d + x^*(t) \tag{53}$$

where e^{Ct} is a matrix exponential function;

d is a vector of constants; and

$x^*(t)$ is a particular solution of the differential equation.

If we consider the homogeneous part of the differential equation only, we find that $x(t)$ is equal to a linear combination of $e^{\lambda_j t}$ where the λ_j are the characteristic roots of the matrix C. As 't' tends to infinity, the solution is dominated by the particular term in the solution corresponding to the highest λ_j. The proportions of the various commodities to each other in the long run are determined by the components of the characteristic vector corresponding to the dominant characteristic root. We would be able to have balanced growth only if the initial configuration of outputs corresponded to this proportion. In that case, output would follow what has been called a Leontief trajectory. The question remains, however, as to whether non-negative output levels will be obtained as solutions. It has been shown by Solow (72) and Tsukui (77) that the system is unlikely to be viable in this sense.

This rigid structure of the Leontief trajectory is due solely to the assumption made of the existence of no excess stocks. If this is relaxed, we obtain:

$$S(0) \geq C^{-1}\left[S(1) - S(0) + F(0)\right] \tag{54}$$

Generalizing this and transposing, we get

$$C^{-1}S(t+1) \leqslant (I + C^{-1})S(t) - C^{-1}F(t). \tag{55}$$

Since we cannot use $\dot{S} = B\dot{x}$, we do not obtain a differential equation. Rather we can find out inter-temporally efficient paths of capital accumulation over a planning period given initial stocks and levels of consumption for the various time periods. This path would be efficient in the Pareto sense of there not existing any other path which would yield more of some terminal capital without yielding less of some other. The Leontief trajectory, if it exists, can be proved to be an efficient path (26). However, there exist many such efficient paths, and a choice has to be made among them on the basis of some criteria. Thus, choice is a basic feature of any dynamic model of capital accumulation.

We have so far made a study of optimal savings models. These have all maximized some kind of utility function subject to production constraints. The solutions obtained were time paths of consumption or production which would maximize the utility function. Subsequently we studied production constraints which were more complex than those considered in the optimal savings model. We found that several efficient time paths of consumption and accumulation could be derived. To choose the optimal one from them, an objective function has to be defined. This function ought to be defined in the utility space as is done in the optimal savings models, but the problem of defining an appropriate utility function is a very difficult one. We therefore define our objective function in the commodity space, and obtain our programming models.

There is a vast literature on programming models for planning. An extensive survey would be both time consuming and redundant. We shall identify the various models by the types of problems that they try to

solve, but first some general statements and explanations about linear programming models are in order.

(4) Linear Programming Models

The general problem

A linear programming problem has the general form

$$\max C'x \quad \text{subject to } Ax \leqslant b$$

$$x \geqslant 0$$

where b, C and x are n x 1 vectors and A is an m x n matrix with $m < n$.

Definitions: "A linear program is called 'feasible' if there exists a vector (x) satisfying the constraints. Such a vector is called a feasible vector.

"A feasible vector is called an optimal vector if it maximizes (or minimizes) the given linear form, and the value of this maximum (or minimum) is called the 'value' of the program." (Gale (31))

Corresponding to the above primal problem, we obtain a dual of the form:

$$\min p'b \quad \text{subject to } p'A \geqslant c'$$

$$p' \geqslant 0.$$

There are various duality properties of linear programming models which are used in the analysis of planning models. The solution to the dual problem informs us as to which of the primal constraints are binding. If a particular variable has a zero value in the dual solution, it implies

that the corresponding constraint in the primal solution is not binding. If the value is positive, it means that the constraint is binding. These values are referred to as 'shadow prices'. A high shadow price informs the programmer that the corresponding primal constraint is very effective. The numerical value of the shadow price is the amount by which the value of the objective function can be raised by relaxing the constraint by one unit.

The exact form of the objective function and the constraints have to be specified when formulating a linear programming model. Of these, we have already discussed the problems of formulating the objective function. For finite horizon programming models, some specification of terminal stocks are needed. This could be done by making terminal stocks appear in the objective function along with consumption, or by including it as a constraint.

The constraints are usually obtained from three types of sources. First, some of them are obtained from the requirement that the supply of any product has to be at least equal to the total direct and indirect demand for it from all sources. These constraints are technological and are obtained from the input-output table. Second, behavioural relations have to be incorporated, e.g., the savings function. Third, certain boundary conditions have to be specified. These could be specified by technology (e.g., ceilings on certain types of production), economic factors (e.g., world demand sets limits on export possibilities), or non-economic factors (e.g., nutritional requirements set minimum levels of consumption necessary for survival). The existence of multiple constraints does make it rather difficult to give an exact interpretation to the shadow prices

which are obtained by solving the dual problem. Mathematically, we can still say that the shadow price reflects the contribution to the objective function made possible by relaxing the constraint by one unit. As we include greater numbers of non-economic constraints, however, it becomes more and more difficult to put meaningful economic labels on the shadow prices.

The standard literature on the subject broadly differentiates between static and dynamic models. The difference generally comes about because of the assumption of different theories to explain investment. In static models, investment (whether constant or growing at a certain rate) is specified exogenously. In dynamic models, investment is explained from within the model, usually by some sort of accelerator theory. This provides the link between economic variables in different periods, and necessitates them being solved simultaneously. A distinction is also made between open-looped and closed-looped models. In the open-loop models, the policy and exogenous variables determine the endogenous variables. In the closed-loop models, the policy variables are themselves determined endogenously by some kind of control rule. Lance Taylor (73) has given a fairly exhaustive survey of the mechanics involved in formulating different kinds of linear programming models.

The point arises as to whether it is worthwhile to introduce these complicated models when simple projections could yield results, and as Manne (58) has noted, perhaps more accurate ones for certain times. The truth is, however, that these multi-sectoral models enable us to understand the workings of the economy, and satisfy the requirement of consis-

tency, which simpler models perhaps do not. The inaccurate use of data and misspecification of relations could lead to faulty results. However, it is only by understanding the mechanism by which the economy works that we can diagnose its ills and propound solutions. The proof of the pudding is more than merely in the eating.

We turn now to a consideration of the various problems which have been presented in a linear programming framework.

Problem #1: the determination of comparative advantage

Several models have been built by Bruno (10,12,20) to examine the most efficient use of foreign aid when planning for imports. It is thus an empirical extension of the Heckchsher-Ohlin theory with more than two factors. Bruno ranks the various industries according to comparative advantage and also determines how these rankings change through time because of changes in the various parameters of the system. These exercises are worked out under varying assumptions about skill formation. In one version, the total availability of labour with each kind of skill is assumed fixed, whereas in the other allowance is made for investment in skill formation. Also in some models, there are overall savings constraints and in others there are not. The effectiveness or non-effectiveness of the savings constraint is the basis of an important distinction made in planning models and has led to the emergence of the two-gap theory which will be considered later.

Combining the above assumptions in different ways, we can obtain several variations of the model. The basic idea behind his models may

be understood by studying the diagram below.

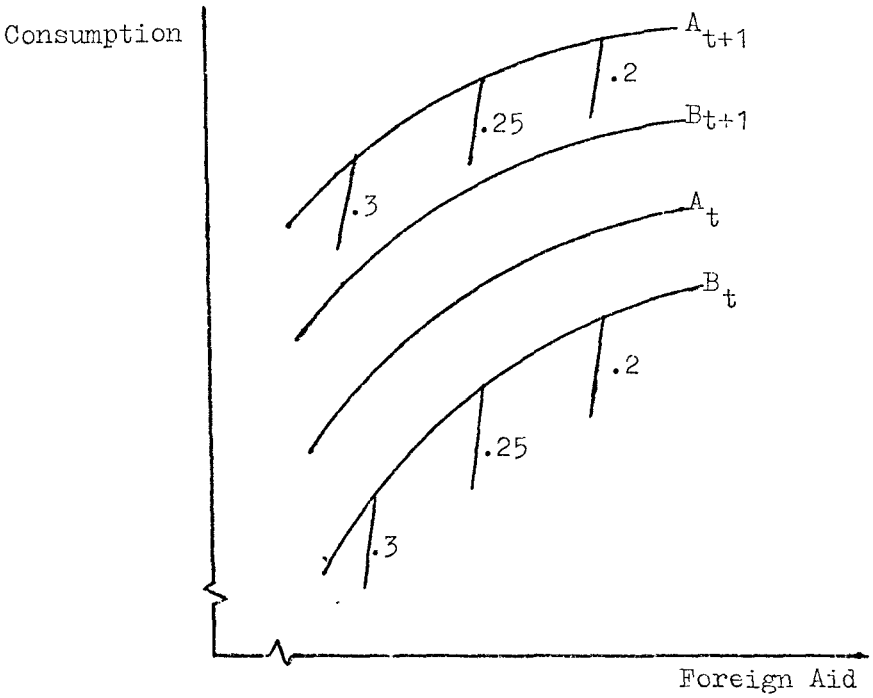

Figure 2

These graphs are obtained by solving the linear programming problem and obtaining consumption figures for different amounts of foreign aid. They reflect diminishing returns to foreign aid. The subscripts t, t+1 refer to different time periods. 'A' allows manpower training programmes, whereas 'B' does not. 'A_t' is thus uniformly higher than 'B_t'. The smooth curves are drawn to reflect cases where savings constraints are not present. The 'kinky' curves represent cases where they are. The lower the constraining savings rate, the higher is the cut-off point. This is to be expected because if very small amounts of domestic savings are available, a very large quantity of foreign aid will be neces-

sary before total savings ceases to be a limiting factor for investment. The slopes of these curves represent the shadow price of foreign exchange.

In a later variation of this model, Bruno (10) introduced upper and lower bounds on 'trade activities' (exporting or import substitution). This imposed kinks in the curves to reflect the fact that a particular 'trade activity' had reached its upper bound, and some other means of obtaining foreign exchange had to be found. 'W' is a curve showing the tradeoff between consumption and foreign aid necessary to keep the economy on the same level of welfare.

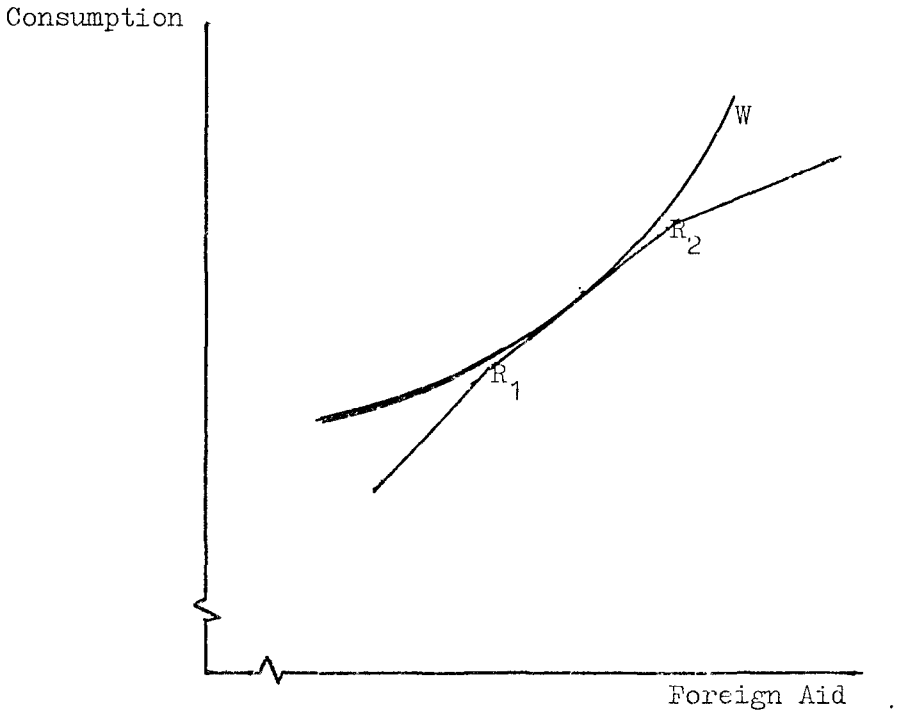

Figure 3

Thus, in the diagram above, the 'trade activity' R is at its minimum level at R_2 and rises to its maximum level at R_1. Over this range of foreign aid, the domestic cost of exports or import substitution is just

equal to the shadow price of foreign exchange. If foreign aid is reduced even further, other less efficient 'trade activities' will become profitable. In this way we can obtain a ranking of industries by their comparative advantages. As the amount of foreign aid is increased, the domestic economy will involve itself in less 'trade activity'. The 'trade activities' which are given up later are obviously in those commodities in which the country has a comparative advantage in international trade. This ranking varies with time and depends upon the given factor endowments. We must note that these curves denote efficient paths. The actual choice of the optimal amount of foreign aid cannot be determined without a welfare function which we have included in our diagram. The ranking of commodities for the purpose of import substitution has been done for India by Weisskopf (78) with a highly disaggregated model. He did not use, however, the linear programming solution technique. Chenery and MacEwan (21) considered the problem of determining the optimal amount of foreign aid for Pakistan. This was one of the two-gap models which we shall discuss later.

In closing our study of this particular kind of model, we can briefly note some of the interesting features in the mathematical structure of the problem. In Bruno's model, allowance was made for upward sloping supply curves and downward sloping demand curves by specifying step functions for them. The size of the model in terms of constraints was reduced by appropriate substitutions which enabled them to be written in terms of final demand vectors and primary input constraints alone.

Bruno distinguished between an earlier static and later dynamic

models. The treatment of investment goods was very unsatisfactory in the static model, however, since they were considered as intermediate goods, and not as additions to capital stock. We shall now turn to models which consider whether domestic savings or foreign exchange limit investment.

Problem #2: domestic and foreign resource mobilization

"Two gap analysis" was first introduced by Chenery and Strout (22). We can comprehend it best by considering a simple model. We assume that imports are made in the investment goods sector only. In other words, the demand for consumer goods imports is either non-existent or can be suppressed by the authorities.

$$S = a + bY \tag{56}$$

$$M = c + dY \tag{57}$$

$$K = kY \tag{58}$$

$$E = E_o e^{gt} \tag{59}$$

where S is savings;

Y is income;

M is imports;

K is capital stock;

E is exports;

a, b, c, d, k, g are the parameters of the system;

t is the time period (values at base year are denoted by the subscript 'o').

Suppose we have a targeted rate of growth of 'r'. Then,

$$Y = Y_o e^{rt} \tag{60}$$

$$\text{or } I = \frac{d}{dt}(K) = \frac{d}{dt}(kY_o e^{rt}) = krY_o e^{rt} \tag{61}$$

Now,

$$S = a + bY_o e^{rt} \tag{62}$$

There is no reason for I = S ex ante.

$$\therefore F_1 \equiv I - S$$

$$= krY_o e^{rt} - a - bY_o e^{rt}$$

$$= Y_o e^{rt}(kr - b) - a \tag{63}$$

gives us the savings gap.

$$F_2 \equiv M - E = c + dY_o e^{rt} - E_o e^{gt} \tag{64}$$

gives us the foreign exchange gap. If either $F_1 > 0$ or $F_2 > 0$ for a certain r, then the 'r' rate of growth is not feasible unless foreign aid is available to cover the larger of the two gaps. If $F_2 > F_1 > 0$, then the foreign exchange constraint is binding, and enough foreign aid is required to bridge the gap between exports and imports. If $F_1 > F_2 > 0$, then the savings gap is binding. Foreign aid is required not only to pay for non-competitive imports, but also to finance additional imports for which domestic resources are not available.

Chenery (21) has attempted to associate different phases of growth with the fact of particular constraints becoming effective. This has been demonstrated in a model built by him and MacEwan for Pakistan. The important technical features of the model are the following:

(1) The objective function is the sum of discounted consumption, weighted discounted capital inflow, and weighted terminal income. The

terminal income is to take account of post-plan consumption.

(2) Since this is an explicit exercise of two-gap analysis, only two kinds of resources are considered — savings and foreign exchange.

(3) There are two kinds of products in the economy — regular and trade improving, which have differing capital-output ratios.

(4) The technique of solution used has been linear programming.

Chenery and MacEwan found that if the amount of aid available was limited, there would be a rapid increase in total investment in the first phase of growth with very little resource being alloted towards trade-improving investment. During the second phase, total investment would stop growing and large allocations would be made for trade improvement. In the third phase, a stable proportion between trade improving and total investment would be reached to make the country independent of foreign aid. We thus find that the foreign exchange gap is much larger than the savings gap in the initial stages, but this gap is closed towards the end.

They have also considered three different ways of limiting foreign aid. The first fixes a terminal date by which time all aid becomes zero. The second fixes the price of aid and the third the total amount of aid. Chenery and MacEwan found from the exercise that these methods are equivalent. Thus, if one fixes the termination date, the solution would determine the price of aid and the total quantity. If either of these values are now used as independent restrictions, one obtains the same allocation and time phasing of growth.

They also find that the sequence of these phases are unaffected by the total amount of aid. However, the length of these phases is af-

fected by the total amount of aid. For example, if the total amount is reduced, the first two phases are shorter. They also show that an earlier termination date does not affect the optimal paths of the variables in phase I.

Problem #3: achieving targeted growth rates

We can now move on to the very ambitious massive planning models which have been built to determine the optimum allocation of resources in a dynamic multi-sectoral setting. These models have obtained complete time paths of vectors relating to different variables in the economy. We can distinguish between two main groups of models in this field: (i) the CELP (Chakravarty, Eckaus, Lefeber, Parikh) models for the Indian economy; and (ii) the dynamic multi-sectoral model by Manne and Weisskopf (59) for the Indian economy, and the DINAMICO model by Manne and Goreux (57) for the Mexican economy. The DINAMICO model is just one of a set of models built by Manne and Goreux for the Mexican economy. The other models, however, do not use the linear programming method of solution. It would be pointless to go into either of these sets of models in great detail. However, since some of the features of these models will be adopted here, we will note some of the more novel features.

CELP:

(1) The terminal capital stock is determined by assuming exogenously given post-terminal rates of growth for various economic variables. This gives rise to a system of vector differential equations which can

be solved for the terminal stocks.

(2) Distribution matrices are used to obtain the requirements of capital goods by sectors of origin from the composite capital stock requirement of the various sectors.

(3) Differing gestation lags are assumed for different types of capital goods by sector of origin. Thus, initial capital-in-process restricts the growth of the capital stock in the early years of planning.

(4) Imports are broken up into competitive and non-competitive types. The latter is determined by an import coefficients matrix and the former is determined by the optimization process.

(5) Provision is made for investment in the stock of inventories.

(6) Provision is made for the restoration of depreciated capital stocks.

Dynamic multi-sectoral (DMS) and DINAMICO models:

(1) A device is introduced to ensure a 'gradualist consumption path'. This requires consumption to grow monotonically, thus preventing initial sharp decreases in consumption with high levels towards the end. This tendency to postpone consumption has been noted earlier in our study of optimum savings models.

(2) The actual 'gradualist consumption path' is chosen such that it would result in terminal investment allocations which would allow the 'turnpike' rate of growth to be approximated. (Note: The 'turnpike' path is one which under certain assumptions allows the maximum rate of balanced growth.)

(3) The DINAMICO model makes allowance for different types of labour skills, thus incorporating manpower planning into the model. Downward mobility between different labour groups is allowed.

(4) DINAMICO is one among seven inter-connected models (not all of them optimized by linear programming techniques) which were constructed for the Mexican economy. The DINAMICO model was for the entire economy, whereas the others covered particular sectors of the economy. This usage of planning at different levels is very widely used in East European economies. Kornai (45) describes two-level planning where an extensive plan covering the entire economy is sent down to the various local bodies, with each body being informed of its specific targets. These numbers are then incorporated into a sectoral model which is solved for shadow prices. These shadow prices are in turn sent back to the centre who revise their plans taking them into account. The final solution is reached iteratively. Kornai has included algorithms for solving this type of problem in his papers. Indian planners could profitably investigate these methods as they are suitable for huge economies, which require coordination between different levels of planning.

We have undertaken a survey of the literature on constrained optimization leading to time paths of outputs, consumption, etc. We have also looked at various planning models which use constrained optimization models in order to derive policy conclusions. Although there have been several planning models drawn up for India, there has yet to be one which determines the optimality or otherwise of income redistribution schemes. This is all the more surprising in a country where a large section of

the people consider themselves to be socialists. We will attempt to fill the hiatus in the chapters that follow.

CHAPTER 4

A LINEAR PROGRAMMING MODEL OF INCOME DISTRIBUTION

(1) A rationale for the model

Most introductory textbooks on Economics begin by asking three fundamental questions, the answers to which are expected to form the cornerstones of the subject. The questions are:

(1) What will the economy produce?

(2) How will the economy produce it?

(3) For whom will it be produced?

The first question is usually answered by saying that the amounts of various commodities produced are determined by the demand for them, as registered by the dollar votes that are cast on their behalf. The second question is generally regarded as a technical matter relating to the efficiency of production processes. As long as sufficient technological information is available as well as data relating to the scarcity of various resources, the solution of the problem is routine. The third question is tackled by saying that the commodities are produced for those people who have the required dollar votes to demand them, these votes being obtained by supplying factors of production that are required in the production process.

In the actual tackling of the problems, however, the assumption is usually made that there exists a given distribution of income which de-

termines what goods are to be produced and for whom they are to be produced. Economic theory, then, provides a neat array of theorems, often proved by the use of sophisticated mathematics, and illustrated by elegant and sometimes complex diagrams, detailing various equilibrium quantity-price configurations that are obtained under different market forms in the commodity market. Questions regarding alternative distributions of income are normative in nature, and are shelved after noting that any redistribution would make some people better off at the expense of others; thus, in the absence of a well-defined social welfare function, no comments could be made on their desirability. Chapters on factor pricing are usually relegated to the end of the textbook; generally they relate factor prices to some concept of marginal productivity and rarely are they completed before the school term runs out.

All this of course has some implications for the economics student. Whereas he has a very clear idea of "what" should be produced and "how", given a certain distribution of income, he is suitably confused on the question of "for whom" it is to be produced, beyond a vague notion that people generally deserve what they get.

This is rather unfortunate and arises, I believe, from the general practice of presenting distribution theory within a neo-classical partial equilibrium framework. What is to be produced is determined by, and also determines for whom it is to be produced. The practice of starting off with a given distribution of income and then finding out the quantities of different commodities to be produced, and the most efficient means of doing so, is therefore suspect.

The size distribution of income depends upon the distribution of factors of production among various people. This includes both the factors of production that are owned by the people as well as those which are embodied in their persons in the form of skills. Both of these depend, by and large, on what was produced in the previous periods, and for whom it was produced. Moreover, a factor price, like a commodity price, depends upon the market form prevailing in its sector. The prevalence of monopsony in the factor market could therefore warrant outside interference, just as the presence of restrictive monopoly practices in commodity markets require regulation from outside. The proposition is therefore forwarded that there is nothing sacrosanct about the existing distribution of income, the general reluctance of economists to discuss it in detail being perhaps attributable to the air of mystery which has always surrounded that subject from their freshman year, in marked contrast to all the charts, diagrams, algebra, calculus which have been used to illustrate other basic concepts.

The above underlines the necessity of fundamental research in economic theory to determine how income distribution is determined by what has been produced in the economy before. The scope of our thesis is, however, more limited in nature. Instead of a theory explaining the distribution of income, we have completely divorced income distribution from production. Now, assuming that income redistribution toward greater equality is desirable for its own sake, we have attempted to find the effects of such redistribution schemes on gross output levels over a five-year planning period. In doing so, we have also determined the areas

in which problems could be expected under alternative redistribution schemes.

(2) The model

The model attempts to explain the effects of various kinds of income redistribution schemes on the economy. The consumption patterns of different income groups differ, so that the composition of the final demand vector is altered every time a new distribution of income is considered. Moreover, the total expenditure of all households depends upon total income which, in the input-output framework, is proportional to the gross output produced. Our model helps to identify the bottleneck years and sectors if a particular type of redistribution scheme is carried out. It also informs us about the feasibility of various kinds of redistribution schemes. This helps the planning authority to guard against sudden shortages in particular sectors at particular times, and also identifies redistribution schemes which are too quixotic to implement.

The use of fixed coefficients production functions and fixed consumption coefficients are limitations of the model. The non-substitution theorem is usually invoked in such cases to justify the use of fixed coefficients on the production side. However, even in a static context, it presumes the existence of only one factor of production. In our case, we have foreign aid and all the initial capacities acting as resource constraints, thus negating the use of this theorem.

The omission of the two classic resources, land and labour, from

explicit considerations as resource constraints in the model, also requires some explanation. The overall supply of land is fixed, but the quality of land can and is being improved. Land measured in efficiency units therefore may not be a fixed constraint in the context of this model. Labour, on the other hand, is a factor which is not in short supply in the aggregate in India, but certain types of skills are scarce. To incorporate this into our model we would require details as regards the supplies of various types of labour, as well as their productivity coefficients in the various sectors. Moreover, these skills themselves are acquired as part of the productive process, for which a separate set of coefficients has to be obtained. The unavailability of these kinds of data, and the desire to keep the model within manageable proportions, has resulted in the omission of the labour constraint from the model.

The economy is aggregated into five sectors: (i) agriculture; (ii) equipment; (iii) manufactured consumer goods; (iv) services and transportation; and (v) construction. The five-sector categorization is sufficient to illustrate the choices that are present in the economy. One can either produce agricultural commodities or manufactured goods or provide services. When manufacturing goods, one has the choice of producing either consumer or capital goods. Substantially more details could be obtained by further subdividing these sectors, but one must remember that the addition of each new sector implies the posing of twelve new constraints even in our simple model. This strains the capacity of the computer considerably, and is, in fact, not necessary, since most of the discussions on planning are concerned with broad choices

of the sort that we are considering. To derive a detailed programme of action we would require the addition of many more sectors, and the enormity of the resulting model would probably lie more within the scope of a government department. Following the tradition of Indian planning, the time horizon is fixed at five years. The objective is to maximize the sum of discounted gross output levels over the five years.

Objective function:

$$\sum_{t=1}^{5} \frac{uX_t}{(1+d)^{t-1}}$$

where X_t is the gross output vector — dimension 5 x 1;

u is the unit vector;

d is the social discount rate.

The above objective function is maximised subject to the several technological and economic constraints which operate within the model. We shall consider five types of constraints:

(1) Intersectoral consistency constraints;

(2) Foreign exchange constraints;

(3) Initial period constraints;

(4) Post-terminal growth constraints; and

(5) Minimum output constraints.

In the exposition below, the subscript 't' always refers to the time period for which the variable is being considered.

(1) Intersectoral consistency constraints: These ensure that the

total demands made on each sector in each year are not greater than the total availability of output in the respective sectors. Let us consider the main items of demand.

(a) Inter-sectoral current demand: these are represented by the input-output flow matrix.

$$a_t = AX_t \tag{1}$$

where a_t is the vector of current flows — dimension 5 x 1;

A is the flow matrix — dimension 5 x 5.

(b) Demand for capital formation: these represent the charges made on each sector for the purpose of capital formation. Assuming that investment is determined by the incremental capital-output ratio, we can obtain:

$$k_t = K(X_t - X_{t-1}) \tag{2}$$

where k_t is the vector of capital required in each sector — dimension 5 x 1;

K is the diagonal matrix of incremental capital-output ratios — dimension 5 x 5.

To produce the k_t which shows the various capital requirements by sector of destination, we need to use resources which originate in the five sectors. The calculation of the requirements by sector of origin tells us the demands that are made on them for the purposes of capital formation:

$$b_{1t} = B_1 k_{t+1} = B_1 K(X_{t+1} - X_t), \tag{3}$$

$$b_{2t} = B_2 k_{t+2} = B_2 K(X_{t+2} - X_{t+1}), \tag{4}$$

where b_{1t}, b_{2t} are the vectors of charges made for capital formation with gestation lags of one period, two periods respectively — dimension 5 x 1;

B_1, B_2 are the matrices of input requirements for producing one unit of capital with one and two period gestation lags — dimension 5 x 5;

$((B_{ij})_1$, $(B_{ij})_2$ are the total amounts of sector i's output required for one unit of new capital formation in sector j, with time lags of one and two years respectively.)

(c) Inventory requirements: we assume that a certain fixed ratio has to be maintained between stocks of inventories and gross outputs. The demand for new inventories should therefore bear a fixed ratio to changes in gross outputs.

$$W_t = W(X_{t+1} - X_t) \tag{5}$$

where W_t is the vector of requirements for changes in inventory stocks — dimension 5 x 1;

W is the matrix of inventory requirements per unit of gross output — dimension 5 x 5.

(d) Exports and government expenditures: these are assumed to be exogenously given. Thus,

$$\left.\begin{aligned} e_t &= \bar{e}_t \\ g_t &= \bar{g}_t \end{aligned}\right\} \text{ 5 x 1 vectors} \tag{6, 7}$$

(e) Consumption requirements: households are divided into the rural and urban sectors. Within each of these sectors a threefold classification is carried out according to the size distribution of income. The upper income group comprises the richest 20% of households and the lower group contains the poorest 30% of households. The rest are classified in the middle income group. The following subscripts are used to denote each of these groups:

Rural Sector	Urban Sector
R1 is the bottom 30%	U1 is the bottom 30%
R2 is the middle 50%	U2 is the middle 50%
R3 is the upper 20%	U3 is the upper 20%.

C_{R1}, C_{R2}, C_{R3} are the vectors showing ratio of expenditure in a particular sector to total expenditure for each rural group — dimension 5 x 1 each. C_{U1}, C_{U2}, C_{U3} may be similarily defined for the urban groups.

$$V_t = \alpha \cdot u \cdot X_t \tag{8}$$

where V_t is the value added, and

α is the ratio of value added to gross output.

$$F_{xy_t} = C_{xy}(1 - s_{xy})\beta_{xy} \cdot V_t, \tag{9}$$

$x = R, U; \quad y = 1, 2, 3;$

where F_{xy} is the final consumption demand vector of income group xy — dimension 5 x 1;

s_{xy} is the average propensity to save of group xy;

β_{xy} is the proportion of total income going to group xy.

The values given to the individual β's determine the pattern of income distribution. They act as shift parameters in the model.

Intersectoral consistency requires that total demand be less than or equal to supply. Aggregating equations 1, 3, 4, 5, 6, 7, 8, and 9, we obtain total demand. Total supply equals domestic production and competitive imports. This is distinguished from non-competitive imports, which are required directly as a fixed proportion of gross output to facilitate production. For intersectoral consistency, therefore, we require:

$$AX_t + B_1K(X_{t+1} - X_t) + B_2K(X_{t+2} - X_{t+1}) + W(X_{t+1} - X_t) + \bar{e}_t + \bar{\varepsilon}_t + \sum_x \sum_y \sum_{x \neq y} (1 - s_{xy})\beta_{xy} \cdot \alpha \cdot uX_t \leq X_t + M_t \quad (10)$$

where M_t is the competitive imports vector — dimension 5 x 1.

(2) Foreign exchange constraint: This is the only fixed resource constraint in the model. The total supply of foreign exchange is given by exports and foreign aid, both of which are exogenous. The demand for foreign exchange takes the form of the demand for imports — competitive and non-competitive. This has to be less than or equal to the total availability of foreign exchange. Thus:

$$u(M_t + m \cdot X_t) \leq \bar{h}_t + u \cdot \bar{e}_t \quad (11)$$

where m is the diagonal matrix of non-competitive import requirements per unit of output produced — dimension 5 x 5;

$\bar{\Pi}_t$ is the foreign aid.

(3) Initial period constraints: The level of capital formation in the pre-plan years sets a limit to the amount of production possible in the first two plan years, because of the two period gestation lag assumed. This can be represented as:

$$X_1 \leqslant \bar{Z}_1 \tag{12}$$

$$X_2 \leqslant \bar{Z}_2 \tag{13}$$

where $\bar{Z}_1$, $\bar{Z}_2$ are the vectors of maximum outputs possible in the first two plan years — each dimension 5 x 1.

(4) Post-terminal growth constraints: There are also certain terminal capital requirements built into the model. For our original set of "runs", we assume that gross output levels in the two post-terminal years are the same as that obtained for the final year.

$$X_5 = X_6 = X_7 \tag{14}$$

Later sensitivity tests are made to see how the results obtained change when alternative post-terminal growth requirements are assumed.

(5) Minimum output constraints: Due to the linear nature of the model, corner solutions result. So, a zero output level for a particular sector in some year is a distinct possibility. However, such a solution would be feasible in our simplified model only because of the neglect of a myriad other constraints which have not been incorporated. The

presence of this possibility, however, limits the usefulness of the model. We thus include several minimum output restrictions as a proxy for these other constraints. These minimum output figures are derived mainly from biological and sociological considerations. They are, however, a crude representation of the actual constraints imposed by these factors. They are used because of the extreme difficulties faced in quantifying these actual restrictions, and the lack of adequate data on this score.

$$X_t \geqslant \bar{L}_t \tag{15}$$

where $\bar{L}_t$ is the vector of minimum outputs.

Our problem can then be formally written as

$$\text{maximize} \sum_{t=1}^{5} \frac{uX_t}{(1+d)^t}$$

subject to

$$\left[I - A + B_1K + W - \sum_x \sum_y (1 - s_{xy})\beta_{xy} \cdot \alpha \cdot u\right] X_t - \left[B_1K - B_2K + W\right] X_{t+1}$$

$$- B_2K \cdot X_{t+2} + M_t \geqslant \bar{e}_t + \bar{g}_t; \tag{10}$$

$$X_5 = X_6 = X_7 \tag{14}$$

$$u \cdot m \cdot X_t + u \cdot M_t \leqslant \bar{h}_t + u \cdot \bar{e}_t; \qquad t = 1, 5; \tag{11}$$

$$X_1 \leqslant \bar{Z}_1; \tag{12}$$

$$X_2 \leqslant \bar{Z}_2; \tag{13}$$

$$X_t \geqslant \bar{L}_t; \qquad t = 1, 5. \tag{15}$$

In the above system, after the appropriate substitutions, we have a total of 65 inequalities (25 corresponding to (10), 5 to (11), 5 to (12), 5 to (13), and 25 to (15).). There are a total of 115 variables to be

determined by the linear programming problem (25 gross outputs, 25 competitive imports, and 65 slack variables). The 50 output and import levels, therefore, represent the choices available to the policy maker. The particular levels which maximize the value of the objective function depends upon the kind of income redistribution policy envisaged (i.e., the values of the β_{xy}'s). These could act as guides to the planner in setting output targets, once a particular kind of redistribution policy has been selected for implementation. Moreover, the shadow prices obtained by solving the dual to the problem informs the planner of potential bottleneck areas and also guides him on the most efficient use of foreign exchange. The feasibility, or otherwise, of the plan under particular types of income redistribution schemes are also determined. It therefore proves to be a very useful instrument if the government embarks upon quantity planning. Even otherwise, the identification of bottleneck areas enables the planner to anticipate problems. It is usually a good idea to size up a bridge before one attempts to cross it.

(3) The application

There are mainly three sources of original data used. These are (i) A Technical Note on the Approach to the Fifth Plan of India 1974-79, (Government of India, Planning Commission, April 1973)(40); (ii) Draft Outline for the Fifth Plan (Government of India, Planning Commission)(39); and (iii) National Council of Applied Economic Research data (63).

Beyond these, a few tables were adapted from Planning for Growth by Eckaus and Parikh (28).

It is assumed that the planning period is five years, and that there are five sectors in the economy. These are:

(1) agriculture;

(2) equipment-manufacturing industries (Mainly industries which have derived demands for their products);

(3) consumer goods industries;

(4) services and transportation; and

(5) construction industries.

Sectors (2) and (5) only are assumed to provide supplies for capital formation. Supplies from sector (2) contribute to capital formation one period later, and those from sector (5) two periods later.

Both the technical note and the draft outline of the fifth plan provide a 66-sector classification of the economy. Whenever data from these sources have been used, the 66 sectors have been collapsed into five in the following manner:

Our classification	Planning Commission's classification
1. Agriculture	1. Foodgrains
	2. Other agriculture
	3. Animal husbandry
	4. Plantations
	5. Forestry
	11. Sugar and gur
	12. Vegetable oil

	13. Tea and coffee
	14. Other food products
2. Equipment	6. Coal
	7. Miscellaneous coal and petroleum products
	8. Iron ore
	9. Crude oil
	10. Other minerals
	23. Fertilisers
	24. Inorganic heavy chemicals
	25. Organic heavy chemicals
	29. Other chemicals
	30. Petroleum products
	32. Refractories
	33. Other non-metallic mineral products
	34. Iron and steel
	35. Non-ferrous metals
	36. Bolts and Nuts
	37. Metal containers
	38. Other metal products
	39. Ball bearings
	41. Agricultural implements
	42. Machine tools
	43. Other machinery
	44. Electric motors

	45. Electric wires
	46. Electronics
	47. Batteries
	50. Telephone and telegraphic equipment
	51. Other electricals
	54. Ships and boats
	55 Aircraft
	56. Rail equipment
	57. Other transport equipment
	62. [illegible]
3. Consumer goods	15. Cotton textiles
	16. Jute textiles
	17. Other textiles
	18. Miscellaneous
	19. Wood products
	20. Pulp and paper products
	21. Leather products
	22. Pubber products
	26. Plastics
	27. Cosmetics and drugs
	28. Man-made fibres
	40. Office and domestic equipment
	48. Electrical household goods
	49. Radios
	52. Motor cycles
	53. Motor vehicles
	58. Watches and clocks

	59. Miscellaneous scientific instruments
	60. Other industries
	61. Printing
4. Transportation	64. Railways
	65. Other transport
	66. Other services
5. Construction	31. Cement
	63. Construction.

The following tables were obtained from the technical note by collapsing the 66-sector classification into a 5-sector classification. This was done by simply multiplying the 66-sector technical coefficients by the corresponding gross output levels to obtain the current flow matrix. The 66-sector current flow matrix is aggregated to a five-sector one by the process of adding.

$$A = \begin{bmatrix} .20281936 & .00600970 & .15660305 & .00781281 & .06891044 \\ .04453051 & .33616449 & .12420063 & .02423270 & .14388172 \\ .00327623 & .02022161 & .19326021 & .01458008 & .02203813 \\ .07241034 & .15856755 & .10823021 & .04870775 & .13151783 \\ .01238643 & .02264744 & .01879003 & .01275309 & .12772695 \end{bmatrix}$$

$$M = \begin{bmatrix} .00540165 & 0 & 0 & 0 & 0 \\ 0 & .06675555 & 0 & 0 & 0 \\ 0 & 0 & .04166538 & 0 & 0 \\ 0 & 0 & 0 & .00158654 & 0 \\ 0 & 0 & 0 & 0 & .00791580 \end{bmatrix}$$

$\bar{e}_t$ and $\bar{g}_t$ for the pre-plan year (1973-74) and for the terminal year (estimate) of the plan (1978-79) were obtained from the technical note. The 66-sector classification was again aggregated to a five-sector one. The vectors for the intermediate years were obtained by interpolating linearly between these two figures.

'α' was estimated also from the technical note, and was found to be equal to .611655963 for the economy as a whole. The value added for the economy as a whole was divided by the gross outputs aggregated over all the sectors to obtain this figure.

'h_t' has been maintained at a level equal to the maximum of the five pre-plan years for the first four years of the plan, and has been assumed to be zero in the terminal year of the plan. This is in concurrence with the plan objective of independence from foreign aid by the end of the plan period. It also allows for the fact that if this objective is to be realised, it may be necessary to use foreign aid to the maximum amount available during the first four years of the plan. The figures for 'h_t' are obtained from the Draft Outline of the Fifth Plan.

Several tables have also been obtained from Eckaus and Parikh's Planning for Growth. The correspondence between Eckaus and Parikh's sectoral classification and our's is the following:

Our classification	Eckaus and Parikh's classification
1. Agriculture	1. Agriculture and plantations
2. Equipment	2. Mining and metals
	3. Equipment
	7. Electricity

3. Consumer Goods	4. Chemicals (including rubber, petroleum products)
	5. Cement, glass, wodden products, etc.
	6. Food, clothing and leather
4. Services and Transportation	8. Transport
5. Construction	9. Construction
	10. Housing
	11. Others and margin.

The following tables were derived by collapsing Eckaus and Parikh's 11-sector classification to our 5-sector classification.

$$K = \begin{bmatrix} 1.510 & 0 & 0 & 0 & 0 \\ 0 & 1.794 & 0 & 0 & 0 \\ 0 & 0 & .785 & 0 & 0 \\ 0 & 0 & 0 & 2.173 & 0 \\ 0 & 0 & 0 & 0 & 1.612 \end{bmatrix}$$

The B_1 and B_2 matrices parallel the p', p", and p"' matrices of Eckaus and Parikh (28). Sectors 3, 9, and 11 (according to their classification) contribute to capital formation. Sectors 3 and 11 have gestation lags of two years, and sector 9 a lag of three years. These sectors are assume to produce uniformly over time, e.g., the equipment sector producing for capital formation two years hence produces half of its required output in the first year and half in the second year. We have assumed that sector 2 (according to our classification) has a gestation lag of one year and sector 5 a lag of two years. We proceed as if the entire

two period production process in the construction industry requires resources to be allocated to it in the first year of production. This is based on the assumption that the government allocates the resources at the beginning of the project. In terms of figures, it means that the B_1 matrix will have positive numbers along its second row only, and the B_2 matrix will have them along its fifth row only.

$$b_1' = B_1 \cdot K = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ .21895 & .92681 & .43438 & 2.173 & .09071 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$b_2' = B_2 \cdot K = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1.28803 & .86434 & .34999 & 0 & 1.5216 \end{bmatrix}$$

The W matrix was obtained by collapsing Eckaus and Parikh's 11 x 11 table into a 5 x 5 one:

$$W = \begin{bmatrix} .318 & .007 & .189 & 0 & .007 \\ .001 & .275 & .240 & .003 & .026 \\ .074 & .037 & .179 & .016 & .036 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

The consumption expenditure ratios of various commodities in the

different income groups are computed from the 66-sector table available in the technical note. The data available in the technical note was given separately for the rural and urban sectors by decile groups. In order to aggregate over the different groups to obtain our three-group classification, we had to know the figures for the proportion of income going to each decile group. This was obtained from NCAER data. Assuming savings rates of 0.1 and 0.2 for the middle and upper income groups respectively, we could convert income distribution figures into expenditure distribution figures. It may be noted that the assumption of these savings rates for the various groups results in an average savings rate of approximately 15%, which is close to the national average.

$$C_{3R} = \begin{bmatrix} .50279406 \\ .02276143 \\ .16919947 \\ .27928101 \\ .02596403 \end{bmatrix} \quad C_{2R} = \begin{bmatrix} .54992506 \\ .02110958 \\ .16288959 \\ .24419935 \\ .02187642 \end{bmatrix} \quad C_{1R} = \begin{bmatrix} .72224018 \\ .00832735 \\ .12248240 \\ .13435103 \\ .01259903 \end{bmatrix}$$

$$C_{3U} = \begin{bmatrix} .41282627 \\ .03980245 \\ .17689075 \\ .27551445 \\ .09496608 \end{bmatrix} \quad C_{2U} = \begin{bmatrix} .42285470 \\ .03978867 \\ .17004262 \\ .27101454 \\ .09629947 \end{bmatrix} \quad C_{1U} = \begin{bmatrix} .56229525 \\ .04437262 \\ .14157278 \\ .19666642 \\ .05509293 \end{bmatrix}$$

From NCAER data we know that the ratio of rural families to urban is 4.89:1, whereas the ratio of value added in the rural sector to that

in the urban sector is 2.474:1. We also know the income distribution pattern within the rural and urban sectors separately. With the aid of these figures we can calculate the β_{ij} for the reference solution.

To calculate $\bar{Z}_1$ and $\bar{Z}_2$, we compute the sectoral growth rates over the five years preceding the plan period. It is assumed that enough capital is available to support these rates of growth over the first two years of the plan period.

$\bar{L}_t$ is obtained by a different method for each of the sectors. Since we have assumed a two-period gestation lag, output in the first two years of the plan is constrained more than in the later years. In all of the sectors therefore, the minimum output levels required in the first two periods are necessarily lower than those in the following years. These constraints are most important for the two consumption sectors, i.e., sectors 1 and 3. For sector 1, which includes foodgrains, we postulate a minimum output requirement which is 2/3 of the level attained in the last pre-plan year. It is to be noted again that this is a boundary condition imposed because of the linear nature of the model. It in no way recommends that these conditions be strictly satisfied. It merely prevents one from obtaining absurd results, (e.g., zero levels of output in a sector in four of the plan years, and a huge amount in the remaining year) which could occur because of the linearity of the model.

In the consumer goods sector (sector 3) output is required to never fall below half the level of the pre-plan year.

In the transportation and other services sector (sector 4), production is required to be at least 3/4 of the pre-plan level in the

five years. It is expected that in a service sector, some cutbacks in personal consumption can be effected, even though the requirements for production purposes have to be satisfied.

In the sectors contributing to capital formation, boundary conditions are least significant, since the demand for such products are derived from their usefulness in producing other commodities. Their requirements are fully laid out in the structure of the input-output model itself, i.e., no separate boundary conditions are required to incorporate factors outside the model as is the case with the consumption goods sectors. At the risk of labouring the obvious, it must be pointed out that production in these sectors add to the stock of capital, and therefore low outputs in these sectors imply low investment, but not necessarily a low level of capital stock.

In sectors 2 and 5, we fix the minimum output level at a nominal amount.

It should be noted that, subject to the basic political, sociological, and biological conditions being satisfied, the minimum output requirements should be made to constrain the feasible region as little as possible in order to give full scope to the optimizing process to work itself out.

The percentage of total rural and urban incomes accruing to each group within their respective sectors is obtained from NCAER data. The breakup is as follows:

Table 1

Income groups	% of rural income	% of urban income
Lowest 30%	12.18	9.65
Middle 50%	42.57	36.36
Upper 20%	44.65	53.99

Without being sharply analytical, one can notice that the income distribution is rather skewed. Our reference solution (Case 1) is run with these income distribution figures, i.e., the existing distribution.

Sixteen other cases have been considered, each of them corresponding to a different type of redistribution program.

Table 2

	Equalization between		
	Lower and middle income groups	Middle and upper income groups	All income groups
Both urban and rural sectors separately	Case 2	Case 11	Case 13
Rural only sector	Case 3 (4)	Case 7 (12)	Case 14 (16)
Urban only sector	Case 5 (6)	Case 8 (9)	Case 15 (17)

The cases outside the brackets assumed that the households retained the consumption pattern of the group to which they originally belonged. The cases listed within the brackets assumed that households change their consumption patterns instantaneously, and adopt those of the new income group to which they move. Thus we have considered the two extreme pat-

terms of consumption adjustment. The actual adjustment pattern will lie somewhere between these two extremes.

Case 10 corresponds to the redistribution of income between the urban and rural sectors so that the average rural family has the same income as the average urban family.

The results obtained are discussed in the following chapter.

CHAPTER 5

The Results: An analysis

1. Introduction

In order to avoid a taxonomic approach to the study of the results obtained in the different "runs" of our model, we should clearly define the main objectives of our exercise. They are:

(1) to determine how different kinds of income redistribution schemes affect gross production levels, and therefore determine the allocations of resources;

(2) to pinpoint the principal bottleneck sectors when these redistribution schemes are put into effect; and

(3) to find how sensitive are the results to alternative assumptions regarding the social discount rate, the foreign exchange availability, the terminal capital stock requirements, and the savings rate.

Policy recommendations will accordingly be made on the desirability of these three kinds of redistribution, and the implications of these policies will be spelt out in detail. The policies are always based on the results of the simulation exercises. In each case, redistribution between the groups concerned is assumed to be carried out until perfect equality of income is obtained.

The shadow prices obtained by solving the "dual" to these linear programming problems will be studied in detail, since they furnish us

with information on the "bottlenecks" which arise when these different kinds of redistribution schemes are effected.

Finally, a comparison between our recommendations and the government of India's policy will be made to see how far official policy is in line with the government's objective of redistributing income.

2. A summary of the results

The principal results obtained from our redistribution exercises are the following:

(1) A completely egalitarian distribution of income in the economy as a whole, or in either sector individually, is infeasible.* This kind of redistribution would imply the transfer of income from the upper to the lower income group, while leaving the income of the middle group in approximately the same position as before;

(2) Rural redistribution schemes, in general, give a higher value for the objective function than do urban redistribution schemes;

(3) Redistribution between the two lower groups yield higher valued objective functions than redistribution between the two upper groups;

(4) Allowing an instantaneous adjustment of consumption patterns

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* - A linear programming problem is infeasible if there does not exist any solution vector satisfying the constraints of the system.

in response to income changes sometimes results in higher values of the objective function and sometimes in lower values;

(5) A redistribution of income between the upper two rural groups, allowing for instantaneous adjustment of consumption patterns, is infeasible;

(6) A redistribution of income against the town and in favor of the country is feasible, and results in a higher value of the objective function than that obtained for the reference solution;

(7) The results obtained are insensitive to a change in the discount rate. When a discount rate of 5% is used, the results are completely insensitive. A 20% discount rate yields a different time profile of gross production, with more being produced in the earlier years. However, the results obtained regarding the relative efficiencies of the various redistribution schemes still remain the same as in the original simulations;

(8) A high discount rate results in extremely low levels of construction in the first two plan years;

(9) Lowering the foreign aid availability from the assumed Rs. 5000 million in the first four plan years to a nominal Rs. 500 million leads to upper-middle income urban redistribution schemes becoming infeasible. The results that are feasible, however, are still in line with our conclusions about

the efficiencies of the various schemes vis-a-vis each other;

(10) If terminal capital stocks are required to maintain the post-plan growth of production as envisaged in the Draft Fifth Five Year Plan, we do not obtain feasibility in any of the cases;

(11) The assumption of higher savings rates makes it possible to successfully equalize incomes between all three income groups.

Before moving to a detailed study of the results obtained under the various redistribution schemes, a study of the relative magnitudes of the objective functions proves interesting. They are shown on the following page (Table 1) in descending order of magnitude.

The highest value of the objective function is obtained when income is redistributed between the lower and middle income groups in the rural sector. The value obtained in this case is higher than that of the reference solution, which has been run assuming the actual prevailing distribution of income. This is a very encouraging result, since most of the statements about redistribution are made with a view to alleviating the plight of the rural poor, who live under the subsistence level of income. The result tells us that such a redistribution should be effected not only for humanitarian reasons, but also because it results in a higher level of gross output over the five plan years. This is a very powerful result, since most policy recommendations are made after considering various kinds of trade-offs. In this case, what we intuitively deem to be fair, also results in a higher level of output.

The above results are not surprising, since a study of the shadow

TABLE 1

	Type of Redistribution	Value of Objective Function (in Rs. million)
Case 4	Between Lower and Middle-Rural (Adjusted Ratios)	2463252.1711
Case 2	Between Lower and Middle-Rural and Urban	2443211.0067
Case 3	Between Lower and Middle-Rural	2437249.5425
Case 10	Between Rural and Urban Sectors	2426694.7110
Case 7	Between Upper and Middle-Rural	2420500.2950
Case 1	Reference Solution	2407804.1109
Case 5	Between Lower and Middle-Urban	2406730.5727
Case 6	Between Lower and Middle-Urban (Adjusted Ratios)	2402674.6038
Case 8	Between Upper and Middle-Urban	2385460.8733
Case 9	Between Upper and Middle-Urban (Adjusted Ratios)	2376675.5010
Cases 11 to 17 are infeasible		

prices (see Table 3) show that agriculture is not the bottleneck sector in any year in the plan. A higher share of income going to the rural poor, results in a greater demand for agricultural products, and a lower demand for manufactured consumer goods, which consistently have higher shadow prices. To produce consumer goods, moreover, a higher proportion of equipment and services are required. Both these sectors have high shadow prices, especially in the early years of the plan. All these factors result in less strain on the system when redistribution between the rural lower and middle income groups is carried out.

The lowest value of the objective function is obtained when redistribution is effected between the urban upper and middle income groups. This, too, is to be expected, since the urban middle class constitutes a group of people who have a very high demand for manufactured consumer goods. This is due to factors like the demonstration effect of consumption in advanced countries, new wants created by the rapid spread of education and technology, and a desire to emulate the style of living of the upper income groups within the country.

If we assume that any movement toward egalitarianism is desirable for its own sake, we could say that redistribution between the rural lower and middle classes is most desirable, and that between the urban upper and middle classes least desirable, albeit desirable all the same.

The results obtained above are to be expected. It has been noted that the rise of the urban middle class has resulted in the upsurge in demand of all kinds of manufactured consumer goods, which have created tremendous pressures on the economy. The relevant question is not (as has been sometimes mistakenly posed) whether the country can make manufactured consumer goods. It is rather that if she does make them, will she have enough resources to maintain production in other key sectors, which are necessary to raise the level ofproduction in the long run. The problem is one of the oldest in economics — that of choosing a production point on the country's transformation schedule. Since this is a dynamic model, every time a point is chosen on a transformation schedule the availability of capital for the future is determined, and a new production possibilities curve is obtained. The solution is to obtain a time path

which gives us a high enough growth rate for the planning period, and yet satisfies the basic requirements of the intra-plan years. A study of the reference solution, with which we compare the different types of simulated distribution policies, will be useful at this point.

As shown in Table 2, gross output increases from Rs. 560864.0855 million in the first year to Rs. 594423.4317 million in the final year of the plan — an increase of 5.98%, which is much lower than the growth envisaged (25.5%) in the plan. There could be several explanations for this. The foreign exchange constraint and the consumption ratios have been worked into this model — something which may not have been done when the plan projections were made.* It may also be due to the manner in which our model has been formulated. The use of a discount rate changes the time profile of production so that it is bunched more toward the earlier years. This method may not have been followed by the government, since the providing for future generations may be a much more important part of the government's objectives than it is for the individual. Our model, it must be remembered, has been formulated with a view to ascertaining the effects of various kinds of redistribution schemes within a fixed planning period. This has been done to determine whether they would cause undue hardships or imbalances in the production structure when implemented. We are really interested in their effects on a particular generation of people, and so a discount rate is imposed, on the assumption that people

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* - No details are given on the exact manner in which the plan projections have been made. It is, therefore, difficult to pinpoint the reason for this difference in results.

TABLE 2

Gross Output
(in million Rs.)

		Case 1 Reference Solution	Case 2 Equality between Lower and Middle Groups in Rural and Urban Sectors
Year 1	Agriculture	229367.9759	239721.6298
	Equipment	79718.8725	79491.2916
	Consumer Goods	75604.1300	75604.1300
	Services & Transport	153049.0500	153049.0500
	Construction	23124.0571	22160.2456
Year 2	Agriculture	251663.9773	261713.0319
	Equipment	82286.3148	81644.8351
	Consumer Goods	76485.1900	76485.1900
	Services & Transport	154775.3600	154775.3600
	Construction	15000.0000	15000.0000
Year 3	Agriculture	231751.9149	242008.3175
	Equipment	71935.6671	71339.2535
	Consumer Goods	64235.4312	64351.8597
	Services & Transport	170514.6791	170081.9802
	Construction	37747.4245	27003.7348
Year 4	Agriculture	234587.6242	244415.6748
	Equipment	56932.6429	56134.5392
	Consumer Goods	87204.0432	86989.8039
	Services & Transport	172979.7142	172442.4615
	Construction	30304.8350	30164.7841
Year 5	Agriculture	239827.7443	249137.6632
	Equipment	53253.3830	53338.6763
	Consumer Goods	91515.8579	89744.4982
	Services & Transport	178038.4114	177158.6929
	Construction	31788.0351	31576.0305
Value of Objective Function		2407804.1109	2443211.0067

TABLE 3

Shadow Prices

		Case 1	Case 2
Year 1	Agriculture	.0299	.0159
	Equipment	.6053	.6021
	Consumer Goods	4.8713	4.9216
	Services & Transport	4.8713	4.9216
	Construction	.8303	.8177
Year 2	Agriculture	0	0
	Equipment	1.3373	1.3454
	Consumer Goods	7.4330	7.5318
	Services & Transport	7.4330	7.5318
	Construction	.6589	.6502
Year 3	Agriculture	.3009	.3051
	Equipment	.8985	.9066
	Consumer Goods	1.4113	1.4333
	Services & Transport	.6042	.6095
	Construction	.3110	.3139
Year 4	Agriculture	.1188	.1089
	Equipment	.4683	.4690
	Consumer Goods	.1908	.1972
	Services & Transport	.3433	.3589
	Construction	.1244	.1045
Year 5	Agriculture	0	0
	Equipment	.4994	.5031
	Consumer Goods	0	0
	Services & Transport	.4440	.4444
	Construction	.0647	.0690
Initial Constraints			
Year 1	Agriculture	0	0
	Equipment	0	0
	Consumer Goods	4.2952	4.3516
	Services & Transport	5.8302	5.8877
	Construction	0	0
Year 2	Agriculture	0	0
	Equipment	0	0
	Consumer Goods	5.2007	5.2933
	Services & Transport	7.8036	7.9355
	Construction	0	0

prefer present consumption to future consumption. This assumption is made for most kinds of optimum growth models (44).

Agricultural production rises sharply in the second year of the plan, but then falls, so that more modest gains in output are recorded. This kind of behavior may be explained in terms of the initial capital constraints. Agriculture requires relatively less capital than either equipment, services and transport, or construction. These have to wait until capital is built up, which occurs with a two-period lag. In the interim, agricultural production can take place in order to obtain higher values of the objective function. Agricultural production is 4.56% higher in the final year of the plan as compared with the first year.*

Equipment production rises in the second year of the plan, and then tapers off. This is due to the fact that income is assumed constant over the two post-plan years, thus cutting down on capital requirements for post-plan production. This assumption has also been made with a view to simplifying the model, so that attention can be concentrated on the effects of the various redistribution schemes. These simplifying assumptions can be legitimately made since our main results regarding the relative efficiencies of various income redistribution schemes are insensitive to variations of the parameters involved.

The production of consumer goods increases by 21.05% during the

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* - The model could perhaps be improved by including population growth as a determinant of agricultural consumption, instead of having it only depend on income. In this sense we are being Keynesian. Agricultural shadow prices are, however, extremely low, implying that it is not the bottleneck in the plans. Thus, the simplification should not lead to any serious distortions of results.

five plan years. This figure will probably be lower if higher post-terminal growth rates are postulated. The time path of consumer goods production is interesting. It remains fairly low in the first two years, and actually declines in the third year, when consumer requirements are met by imports. It can be presumed that during this time capacity is being built up to enable the sharp increases in output recorded in the final two years of the plan. The economy is following the classic path of high investment and postponed consumption, which is characteristic of planned economics. In the interim period, the requirements of consumption are met by imports.

The services and transportation sector increases steadily throughout the plan period, recording an overall increase of 16.33%. The steady increase of services and transport points out the importance of these sectors in the growth process, no matter what the time profile of the growth of the various sectors may be. Banking, education, market facilities and transportation are an essential requirement of any kind of productive process. The infra-structure has to be built up in order that a smooth growth path may be successfully followed. It may be compared with the motor oil which is vital for the smooth functioning of any engine. It may not be very visible to the casual observer, but is essential if the engine is not to sputter and die.

The importance of the transport sector cannot be overemphasized. A moment's reflection on the enormity of the size of the country makes the idea of a problem transportation sector very plausible. The plan's emphasis on balanced regional development has made for a fairly uniform spacing

of industries throughout the country. In the absence of comprehensive location planning, the requirements of industries for transportation as input must be fairly high. Add to this the fact that the intra-country transportation network was fairly undeveloped at the time of independence, and we can understand why it proves to be one of the stumbling blocks in the way of swift progress.

The crucial nature of transportation also makes very clear the importance of location planning and multi-level planning. In many socialist countries, planning is a two-way stream. The central planning authority sets targets to be reached nationally, and allocates different portions of it to regional authorities. The regions, in turn, use these targets to calculate the shadow prices of various resources, which are transmitted back to the central authority. The latter use these shadow prices to fix a new revised set of targets, and the process continues. The targets originally set are therefore the initial values for starting an iterative process, which successively approximates the final target. In Indian planning, the process seems to stop with the initial step. The local authorities (who are the only people with knowledge about the availability of local resources), do not have any chance to get into the act. Thus, the computer at New Delhi may find that enough resources are available for a particular industry in the country, not taking into account the fact that the factory may be in Tamilnadu and the resource in Punjab (a distance of over 1500 miles). Planning at a lower level could sort this out, and location planning could help in industries being located close to their source of inputs. This could sufficiently lower the require-

ments of transportation (i.e., change the relevant input-output coefficients) and thus ease the strain on the very crucial sector.

Construction production increases by 37.47% over the entire plan period, thus recording the highest increase of any of the sectors. Construction does not tail off like equipment production, because a large part of demand is for final consumption. Thus even though post-terminal requirements for capital formation are not there, increasing incomes give rise to an increase in the demand for housing accommodation.

A study of the shadow prices (see Table 3) reveals that they are generally higher for the first two years of the plan. This is to be expected since the initial capital endowments restrict the permissible levels of output in the first two years.

Agriculture has a low shadow price throughout the plan. Equipment maintains moderate shadow prices, although it rises briefly in the second year. This can be explained by assuming that construction was proving to be the main bottleneck to capital formation in the first year of the plan, as it works with a two period lag. Once the construction output was forthcoming, the onus rested on the equipment sector in the following period to make the composite capital complete.

The services and consumer goods sectors have high shadow prices in the first two years of the plan, due to the initial capital constraint. The shadow price of consumer goods falls off rapidly, and becomes zero in the final year of the plan. The shadow price of services also falls, but does not become zero at the end.

The construction industry has a high shadow price in the first year of the plan, but falls rapidly, and becomes negligible by the final year.

The shadow price of foreign exchange in any particular year is equal to the maximum value taken on by the shadow prices in the various sectors. The linear nature of the model ensures that all imports are made into those sectors which have the highest shadow price. Certain models (28) prevent this by imposing ceilings on competitive import levels in the various sectors. The failure to do so, however, does not make the model unrealistic. There is reason to assume that all imports should be channelled into one sector, if it is the most efficient policy, given our objectives. This holds with even greater force when we consider the fact that the sectors are in a highly aggregated form.

We have been thus far looking at production levels, imports and shadow prices which optimize our objective function, given the prevailing distribution of income. We now move on to compare these results with those obtained under alternative assumptions regarding income distribution.

3. Redistribution between lower and middle income groups

Redistribution between the lower and middle income groups is feasible in both the rural and the urban sectors. Moreover, it is feasible whether we assume that households retain their old pattern of consumption, or whether we assume that they instantaneously adopt that of

the new income group to which they belong. Their actual behavior would lie between these two extremes.

When a redistribution scheme is put into effect in the rural and urban sectors simultaneously, we still obtain a feasible solution (see Table 2 in the previous section). The value of the objective function ishigher than that obtained for the reference solution. The difference seems to be mainly caused by consistently higher levels of agricultural output in all the plan years. The middle income group's demand is directed mainly toward commodities and services which are in short supply in the economy. This slows up the entire growth process because of the inter-relatedness of the different sectors. The diversion of income away from the middle groups and toward the lower income groups, which consumes a higher proportion of the relatively abundant agricultural produce, accelerates the growth process, and leads to higher values for the objective function than obtained before. Agricultural output is about Rs. 10,000 million higher in each year, whereas outputs in other sectors are slightly lower as compared with the reference solution. Thus, sizeable increases in aggregate outputs result.

Rural redistribution always results in a value of the objective function higher than that for the reference solution. Urban redistribution schemes, although feasible, result in lower values of the objective function. The main reason for this difference again seems to lie with agricultural production. Agricultural production, under urban schemes, although higher than that obtained for the reference solution, consistently yield output levels lower than those obtained under rural schemes. The

TABLE 4

Gross Output

(in million Rs.)

		Equality between lower and middle income groups			
		Case 3 Rural	Case 4 Rural (Adjusted ratios)	Case 5 Urban	Case 6 Urban (adjusted ratios)
Year 1	Agriculture	237590.7868	241513.4000	231638.0070	230287.7525
	Equipment	79515.9413	81302.5123	79131.2464	79459.0435
	Consumer Goods	75604.1300	75604.1300	75604.1300	75604.1300
	Services & Transport	153049.0500	153049.0500	153049.0500	153049.0500
	Construction	22548.4225	23217.4103	22126.3586	22148.9489
Year 2	Agriculture	260052.9914	264913.9900	253006.9300	252938.9775
	Equipment	81740.3688	82964.0930	81401.1904	81563.6831
	Consumer Goods	76485.1900	76485.1900	76485.1900	76485.1900
	Services & Transport	154775.3600	154775.3600	154775.3600	154775.3600
	Construction	15000.0000	15000.0000	15000.0000	15000.0000
Year 3	Agriculture	239833.0415	243708.4220	233863.5023	231883.2773
	Equipment	71445.7536	73775.5748	70963.1327	70852.8548
	Consumer Goods	64345.0796	66531.3407	64124.1591	63445.4225
	Services & Transport	170204.9570	168597.8410	170232.6406	170662.9914
	Construction	37541.0986	37542.0339	36720.3222	38128.2939
Year 4	Agriculture	242354.1681	245931.1620	236269.5813	234100.4662
	Equipment	56348.9565	58870.1636	55639.7685	55679.1764
	Consumer Goods	87071.3014	88812.5192	86865.0840	86126.1717
	Services & Transport	172563.3365	170842.1520	172646.7471	172914.2495
	Construction	30395.0254	30563.9989	30016.0121	30934.1237
Year 5	Agriculture	247322.7829	250700.0940	240914.0632	239112.6347
	Equipment	53275.4609	56308.1739	52812.6070	52920.6049
	Consumer Goods	90275.8828	91152.4834	89554.4647	88501.7578
	Services & Transport	177389.2193	175466.7904	177588.8930	177670.3132
	Construction	31853.0067	31969.0003	31428.9080	32554.3651
Value of Objective Function		2437249.5425	2463252.1711	2406730.5727	2402674.6058

TABLE 5

Shadow Prices

		Case 3	Case 4	Case 5	Case 6
Year 1	Agriculture	.0185	.0071	.0295	.0310
	Equipment	.6027	.5997	.6049	.6050
	Consumer Goods	4.9128	4.9513	4.8697	4.8627
	Services & Transport	4.9128	4.9513	4.8697	4.8627
	Construction	.8200	.8093	.8295	.8305
Year 2	Agriculture	0	0	0	0
	Equipment	1.3442	1.3493	1.3364	1.3353
	Consumer Goods	7.5158	7.5851	7.4286	7.4179
	Services & Transport	7.5158	7.5851	7.4286	7.4179
	Construction	.6518	.6454	.6587	.6590
Year 3	Agriculture	.3044	.3074	.3009	.3003
	Equipment	.9053	.9112	.8982	.8971
	Consumer Goods	1.4296	1.4466	1.4110	1.4082
	Services & Transport	.6086	.6128	.6041	.6033
	Construction	.3135	.3156	.3110	.3105
Year 4	Agriculture	.1107	.1034	.1190	.1195
	Equipment	.4689	.4695	.4683	.4678
	Consumer Goods	.1961	.2009	.1910	.1901
	Services & Transport	.3562	.3677	.3431	.3417
	Construction	.1076	.0944	.1227	.1238
Year 5	Agriculture	0	0	0	0
	Equipment	.5025	.5052	.4993	.4986
	Consumer Goods	0	0	0	0
	Services & Transport	.4443	.4446	.4439	.4436
	Construction	.0683	.0714	.0646	.0642
Initial Constraints					
Year 1	Agriculture	0	0	0	0
	Equipment	0	0	0	0
	Consumer Goods	4.3416	4.3854	4.2941	4.2867
	Services & Transport	5.8777	5.9214	5.8283	5.8202
	Construction	0	0	0	0
Year 2	Agriculture	0	0	0	0
	Equipment	0	0	0	0
	Consumer Goods	5.2781	5.3443	5.1977	5.1882
	Services & Transport	7.9138	8.0084	7.7994	7.7855
	Construction	0	0	0	0

urban lower income group does have a higher demand for agricultural products than does the middle group; however, the difference is not as great as that prevailing in the rural sector. The lower savings rate implied by this redistribution scheme puts strains on the system, and this is not fully compensated by a shift of demand to agriculture. In the case of rural redistribution, there is a lowering of the savings rate, but the massive shift in demand towards the abundant agricultural sector alleviates this strain, and makes higher gross outputs possible.

Comparing the effects of these income redistribution schemes under alternative assumptions regarding the adjustment of consumer behavior patterns, we come across an interesting result. In the case of rural redistribution, the assumption of instantaneous change of consumer behavior patterns leads to a higher value of the objective function than that obtained assuming no change in consumption ratios. In the case of urban redistribution, however, a lower value of the objective function is obtained when allowing for such adjustments. In both the rural and urban cases, the allowance of instantaneous adjustments leads to a lower overall savings ratio. This has a more serious effect under rural redistribution schemes since total rural income is higher than urban. However, the consumption pattern of the intermediate group (i.e., intermediate between the lower and middle income groups) is closer to the lower group's pattern in the rural sector than in the urban. Thus, when rural schemes are implemented, the new intermediate class demands relatively less of manufactured consumer goods which are scarce in the system. The urban intermediate group has a consumption pattern which is much more akin to

that of the middle income group. This feature of consumer behavior can possibly be explained in terms of the demonstration effect, which is understandably more effective in the cities than in the countryside.

The fact that the lowering of the savings rate is more serious for rural schemes than for urban, is borne out by the fact that the shadow prices for adjusted ratio "runs" relative to unadjusted ratio "runs" are higher for the rural schemes than for the urban schemes.

4. Redistribution between upper and middle income groups

This kind of redistributinn is feasible in the rural and the urban sectors, assuming that consumer behavior patterns cannot change. The value of the objective function is higher under rural redistribution than in the reference solution, but it is lower under urban redistribution than in the reference solution. With adjusted consumption patterns, the value of the objective function is still lower under urban redistribution, and the problem becomes infeasible for rural redistribution. A simultaneous equalizatinn in both the urban and rural sectors is also infeasible.

Under rural redistribution, agricultural outputs are consistently higher than the reference solution. Higher agricultural outputs in the second year, which are a feature of every "run", is particularly pronounced in this one. Agricultural output increases by 15.39% in the second plan year, but falls back in the next year to a steady growth rate of about 0.6% per annum.

TABLE 6

Gross Output
(in million Rs.)

		Equality between upper and middle income groups		
		Case 7 Rural	Case 8 Urban	Case 9 Urban (adjusted ratios)
Year 1	Agriculture	241294.9224	229968.8089	227735.4920
	Equipment	71377.4333	78100.0261	77852.5227
	Consumer Goods	75604.1300	75604.1300	75604.1300
	Services & Transport	153049.0500	153049.0500	153049.0500
	Construction	20618.5261	21071.4107	21809.2763
Year 2	Agriculture	279648.7364	250568.1687	245855.1072
	Equipment	65973.5110	80031.0260	80075.4879
	Consumer Goods	76485.1900	76485.1900	76485.1900
	Services & Transport	154775.3600	154775.3600	154775.3600
	Construction	15000.0000	15000.0000	16355.1808
Year 3	Agriculture	240776.8781	231546.5216	230105.3127
	Equipment	48197.1959	69572.4703	69629.8381
	Consumer Goods	63774.1334	63775.2763	64030.3144
	Services & Transport	170018.5967	170026.8715	169781.4256
	Construction	56737.3006	35842.0713	34874.3334
Year 4	Agriculture	244126.5460	233048.0588	231877.4474
	Equipment	18421.7357	54132.9317	53823.4267
	Consumer Goods	89805.2177	86331.0083	86649.7370
	Services & Transport	170571.4444	172330.6724	172323.9423
	Construction	56438.1523	29740.7141	29654.2913
Year 5	Agriculture	248378.2699	235595.1233	234303.1514
	Equipment	15000.0000	52530.8578	51720.3695
	Consumer Goods	105347.4205	88045.2333	88348.1230
	Services & Transport	158831.9927	176385.4383	176638.9153
	Construction	57195.4915	31738.4583	31580.0644
Value of objective function		2420500.2950	2385460.8733	2376675.5010

TABLE 7

Shadow Prices

		Case 7	Case 8	Case 9
Year 1	Agriculture	.0398	.0436	.0604
	Equipment	.6156	.6139	.6305
	Consumer Goods	4.9014	4.8668	4.9111
	Services & Transport	4.9014	4.8668	4.9111
	Construction	.8499	.8498	.8820
Year 2	Agriculture	0	0	0
	Equipment	1.3546	1.3440	1.3702
	Consumer Goods	7.5086	7.4218	7.5256
	Services & Transport	7.5086	7.4218	7.5256
	Construction	.6549	.7512	.7822
Year 3	Agriculture	.3462	.2122	.2309
	Equipment	.9329	.8644	.8925
	Consumer Goods	1.4451	1.3983	1.4346
	Services & Transport	.5890	.6770	.6881
	Construction	.3813	.1696	.1969
Year 4	Agriculture	.0537	.3762	.3987
	Equipment	.4590	.5706	.5993
	Consumer Goods	.2106	.2055	.2338
	Services & Transport	.4341	.0978	.1100
	Construction	0	.5706	.5993
Year 5	Agriculture	.0913	.1103	.6455
	Equipment	.1939	.8200	1.5839
	Consumer Goods	0	.3747	1.1228
	Services & Transport	.4350	.8200	1.2433
	Construction	0	.1022	.7530
Initial Constraints				
Year 1	Agriculture	0	0	0
	Equipment	0	0	0
	Consumer Goods	4.3135	4.2797	4.3048
	Services & Transport	5.8682	5.8275	5.8838
	Construction	0	0	0
Year 2	Agriculture	0	0	0
	Equipment	0	0	0
	Consumer Goods	5.2460	5.1732	5.2301
	Services & Transport	7.8700	7.7682	7.8534
	Construction	0	0	0

The consequence of the greater demand for consumer goods by the middle income group is very noticeable, as gross output in that sector registers an increase of 39.34% over the five plan years, the largest increase registered in this sector for any of the simulation runs. The most spectacular increase is registered in construction, where an increase of over 225% is registered. In order to provide for these increases, the outputs of equipment and services are much below those of the reference solution. In fact, in the case of the former, the output in the last year is equal to the minimum permissible level. This kind of redistribution, however, results in very little capital formation toward the end of the plan, and could therefore result in problems if a longer time horizon than two post-plan years are considered.

If consumption patterns are allowed to adjust, however, we obtain an infeasibility with rural redistribution. This occurs despite the fact that the adjustment makes for higher savings rates than the case where old patterns were assumed to be retained. The infeasibility occurs because the intermediate income group (i.e., in between the upper and middle income groups) has a consumption pattern closer to that of the higher income group. In particular, the high demand for services makes it impossible to cut down on its production in order to provide for consumer goods. This result is not surprising to any person who is familiar with the Indian social structure. The rural upper-income groups are noted for their conspicuous consumption, a lot of which takes the form of the ostentatious consumption of services.

When urban redistribution schemes are implemented, we obtain

feasible results assuming either adjusted or unadjusted consumption ratios. In both cases, however, the value of the objective function is less than that of the reference solution, the value being lower in the case of instantaneous adjustment. The feasibility obtained in the latter case for urban redistribution schemes, and the lack of feasibility for rural redistribution schemes may be explained by the fact that rural schemes affect a larger part of the economy than do urban schemes. Thus when the redistribution is of a nature which increases the strains on the economy, the stresses are much stronger if the redistribution covers a larger volume of income.

The values of gross outputs under either assumption are close to, but uniformly lower than those for the reference solution. This would lead us to suspect that the redistribution does not lead to any drastic change of priorities, but imposes greater strains on the system because of a larger portion of income going to an income group which has a relatively lower savings rate. The demonstration effect for the urban group seems to have worked through at a lower level of income than it does for the rural group.

When comparing shadow prices, we notice that they are roughly equal to those of the reference solution in the early years, but are uniformly higher in the final years. This leads us to think that a permanent redistribution of income toward groups which save less may not impose noticeable strains on the economy in the early going, but the cumulative effect of lower savings each year will be felt toward the end of the plan. The result holds, with even greater force, when we assume that

TABLE 8

Value of Competitive Imports
(in million Rs.)

		Case 1 Reference Solution	Case 2 Equalization between Lower & middle -rural & urban	Case 3 Equalization between Lower & middle - rural	Case 7 Equalization between Upper & middle - rural	Case 5 Equalization between Lower & middle - urban	Case 8 Equalization between Upper & middle - urban
Year 1	Agriculture	0	0	0	0	0	0
	Equipment	0	0	0	0	0	0
	Consumer Goods	5693.2067	5920.6003	5887.3322	7090.0529	5778.7492	5622.9224
	Services & Transport	10790.9120	10530.4131	10570.4730	9906.3112	10740.2324	10971.7408
	Construction	0	0	0	0	0	0
Year 2	Agriculture	0	0	0	0	0	0
	Equipment	0	0	0	0	0	0
	Consumer Goods	2721.8336	2970.0642	2906.1835	2934.7731	2840.0196	2940.6120
	Services & Transport	14781.2192	14521.5289	14587.9992	15506.0855	14714.8654	14687.5412
	Construction	0	0	0	0	0	0
Year 3	Agriculture	0	0	0	0	0	0
	Equipment	0	0	0	0	0	0
	Consumer Goods	20001.8279	19987.9640	19988.4383	21407.4413	20068.5592	20177.0509
	Services & Transport	0	0	0	0	0	0
	Construction	0	0	0	0	0	0
Year 4	Agriculture	0	0	0	0	0	0
	Equipment	21601.7540	21612.8315	21604.2436	23809.6207	21695.9126	21845.1822
	Consumer Goods	0	0	0	0	0	0
	Services & Transport	0	0	0	0	0	0
	Construction	0	0	0	0	0	0
Year 5	Agriculture	0	0	0	0	0	0
	Equipment	17088.4398	17109.3354	17098.8184	0	17193.4249	16732.4511
	Consumer Goods	0	0	0	0	0	0
	Services & Transport	0	0	0	18769.7746	0	545.6156
	Construction	0	0	0	0	0	0

consumption patterns can adjust instantaneously. The shadow prices in this case are much higher than that for the reference solution, and reaches a level of .6455 even for agriculture, which is the highest value obtained for that sector among the feasible solutions.

In general, we could say that equalization between the upper and middle groups impose more of a strain on the system than equalization between the lower and middle groups. Both kinds of equalization lead to lower savings, but whereas in the latter case the redirection of demand away from the bottleneck sectors alleviates this effect, in the former case no such relief is present. In fact, the demonstration effect may work to increase the pressures on the system.

The demonstration effect influences the rural and urban sectors at different income levels. In the rural sector, it comes into operation when a household is between the middle and upper income groups. On the other hand, in the urban sector it sets in for households between the lower and middle groups, and remains as we move up along the income scale. This is not surprising, since urban classes are more exposed to the demonstration effect of elitist consumption than the rural classes.

5. Equalization of average incomes between urban and rural sectors

Equalization of average incomes between the urban and rural sectors is feasible and results in a higher value of the objective function than that of the reference solution. Agricultural outputs are uniformly higher and construction outputs uniformly lower than the reference solution.

TABLE 9

Gross output
(in million Rs.)

Case 10	Agriculture	Equipment	Consumer Goods	Services & Transport	Construction
Equalization of average incomes between urban and rural sectors					
Year 1	235011.9565	79240.5456	75604.1300	153049.0500	22394.0510
Year 2	253413.3245	82597.8754	76485.1900	154775.3600	15000.0000
Year 3	239103.3437	72208.7385	64447.1693	170482.2155	34028.6010
Year 4	242621.6844	56804.7207	87709.1503	173419.6415	27738.7829
Year 5	247023.9093	52686.0690	93577.7119	178537.8573	29178.9295
Value of objective function: 2426694.7110					
Shadow Prices					
Year 1	.0232	.6045	4.9014	4.9014	.8252
Year 2	0	1.3422	7.4846	7.4846	.6552
Year 3	.3031	.9030	1.4224	.6071	.3126
Year 4	.1143	.4690	.1940	.3509	.1142
Year 5	0	.5015	0	.4445	.0667
Initial Constraints					
Year 1	0	0	4.3276	5.8650	0
Year 2	0	0	5.2472	7.8706	0

This reflects the relative pattern of consumption of the country folk vis-a-vis the city dweller. The lessened pressure on the system results in a higher value of the objective function. Redistributing income in favor of the countryside, and against the cities, leads to higher production.

The above result may seem contradictory to the policies followed by most industrializing countries in the early stages of development. Redistributing income against the country is usually recommended in order to ensure an adequate supply of industrial workers for the towns. These workers are supposed to be surplus labor from the countryside who migrate for short stretches of time to the towns, earn and save some money, and return to the villages, which are still their home. Their pattern of consumption is similar to that of the rural household; in fact, their families may still be living in the country. This stage has, however, come and gone. The modern industrial worker is no longer a farmhand temporarily transplanted to the city, but is a permanent dweller of the place, with a life and culture which is all his own. He is no longer a demander of food only, but he wants transistor radios and bicycles as well. Thus, pressures build up on the demand side. In fact, often a worker refuses to leave the town even though he will be better off in his rural home. A policy of redistributing income against him may result in his returning home. The skills which he has acquired during his sojourn at the city could possibly be used in the setting up of decentralized cottage industries, which were a traditional part of the Indian economy, and which declined so tragically with the advent of British rule in India.

6. Sensitivity tests

Several tests have been made as regards the sensitivity of the results obtained to changes in the parameters of the system. We will now look at them in detail.

Social discount rate changes

The simulations were re-run assuming social discount rates of 5% and 20%. The re-runs were made for the reference solution, equalization of lower and middle income groups, and equalizatinn of middle and upper income groups, assuming a retention of old consumption patterns (Cases 1, 2, 3, 5, 7, and 8). Gross outputs were found to be completely insensitive to the change in the discount rate to 5%. For Cases 1, 2, 3, 5, and 7, the gross outputs were identical to the ones obtained in the original run. For Case 8, there were very small changes, but in general the results were insensitive.

The higher discount rate, as expected, affects the time phasing of production. This is illustrated in the Table below:

TABLE 14

Gross outputs for reference solution
(in million Rs.)

	10% discount rate	20% discount rate
Year 1	560864.0855	574558.1435
Year 2	580210.7421	588490.3401
Year 3	576185.1468	567057.2168
Year 4	582008.8595	572200.4616
Year 5	594423.4317	583248.8813

TABLE 10

Gross outputs using a 20% Discount rate
(in million Rs.)

		Case 1 Reference Solution	Case 2 Lower & Middle (Urban & Rural)
Year 1	Agriculture	271620.3240	280170.0484
	Equipment	73284.6395	73559.1209
	Consumer Goods	75604.1300	75604.1300
	Services & Transport	153049.0500	153049.0500
	Construction	1000.0000	1000.0000
Year 2	Agriculture	266052.5746	274666.6611
	Equipment	76177.2155	76299.3352
	Consumer Goods	76485.1900	76485.1900
	Services & Transport	154775.3600	154775.3600
	Construction	15000.0000	15000.0000
Year 3	Agriculture	228206.2021	238453.6682
	Equipment	69603.8050	69738.0769
	Consumer Goods	62803.2463	63070.6100
	Services & Transport	168462.7296	168159.6906
	Construction	37981.2338	36584.8218
Year 4	Agriculture	230919.1211	240643.3594
	Equipment	54104.4872	54269.7338
	Construction	85598.2170	85705.6508
	Services & Transport	170760.4505	170438.1874
	Construction	30818.1858	29947.6164
Year 5	Agriculture	237847.9696	245533.6527
	Equipment	51404.8272	51955.8454
	Consumer Goods	87219.9910	87368.9238
	Services & Transport	175477.2520	174987.7858
	Construction	31298.8415	31161.6465
Value of objective function		2071780.9083	2102951.6465

TABLE 11

Shadow Prices using a 20% Discount rate

		Case 1	Case 2
Year 1	Agriculture	0	0
	Equipment	.5722	.5856
	Consumer Goods	4.7693	4.8823
	Services & Transport	4.7693	4.8823
	Construction	.6111	.6042
Year 2	Agriculture	0	0
	Equipment	1.0713	1.0794
	Consumer Goods	5.7691	5.8069
	Services & Transport	5.7691	5.8069
	Construction	.4496	.4466
Year 3	Agriculture	.2198	.2192
	Equipment	.6988	.7043
	Consumer Goods	1.0649	1.0749
	Services & Transport	.4771	.4847
	Construction	.2255	.2235
Year 4	Agriculture	.0286	.0284
	Equipment	.3372	.3409
	Consumer Goods	.1298	.1334
	Services & Transport	.3125	.3168
	Construction	0	0
Year 5	Agriculture	0	0
	Equipment	.3893	.3974
	Consumer Goods	.0115	.0179
	Services & Transport	.3354	.3447
	Construction	.0720	.0727
Initial Constraints			
Year 1	Agriculture	0	0
	Equipment	0	0
	Consumer Goods	4.2306	4.3309
	Services & Transport	5.7006	5.8354
	Construction	0	0
Year 2	Agriculture	0	0
	Equipment	0	0
	Consumer Goods	3.9274	3.9508
	Services & Transport	6.0154	6.0569
	Construction	0	0

TABLE 12

Gross outputs using a 20% Discount rate
(in million Rs.)

		Rural		Urban	
		Lower & Middle Case 3	Upper & Middle Case 7	Lower & Middle Case 5	Upper & Middle Case 8
Year 1	Agriculture	278796.2586	278454.8959	271813.4360	240380.6784
	Equipment	73412.3361	65969.1671	73173.3514	76602.0185
	Consumer Goods	75604.1300	75604.1300	75604.1300	75604.1300
	Services & Transport	153049.0500	153049.0500	153049.0500	153049.0500
	Construction	1000.0000	1000.0000	1000.0000	15551.1619
Year 2	Agriculture	273480.4862	291235.7600	265989.9589	253704.2299
	Equipment	76160.3936	61186.9575	75968.2192	78737.1004
	Consumer Goods	76485.1900	76485.1900	76485.1900	76485.1900
	Services & Transport	154775.3600	154775.3600	154775.3600	154775.3600
	Construction	15000.0000	15000.0000	15000.0000	15000.0000
Year 3	Agriculture	236259.6784	237367.3078	230347.0602	230609.5374
	Equipment	69633.7124	47082.1108	69328.8102	69350.0257
	Consumer Goods	63017.4238	62564.3069	62815.0787	63426.8762
	Services & Transport	168241.7787	168182.2522	168260.1828	169647.4218
	Construction	37303.7237	55813.4779	36292.7383	35478.7881
Year 4	Agriculture	238588.0675	240431.8296	232533.2715	232095.7402
	Equipment	54206.8470	17295.8187	53736.1546	53933.7469
	Consumer Goods	85692.1801	88563.8720	85551.8978	86026.1230
	Services & Transport	170493.7383	168694.0171	170589.7257	171799.8649
	Construction	30381.3137	55813.4779	29795.9731	29338.0616
Year 5	Agriculture	244157.4296	244469.2756	237347.8675	234620.2492
	Equipment	51757.5445	15000.0000	51404.5753	51590.6138
	Consumer Goods	87347.3591	103064.4561	87226.9991	87735.4129
	Services & Transport	175103.4349	156691.8519	175158.7571	176169.0306
	Construction	31393.1721	66112.2781	31006.4598	31623.9297
Value of objective function		2097693.7196	2082832.5998	2071101.7403	2051050.5385

TABLE 13

Shadow Prices using a 20% Discount rate

		Case 3	Case 7	Case 5	Case 8
Year 1	Agriculture	0	0	0	0
	Equipment	.5832	.5707	.5722	.5630
	Consumer Goods	4.8622	4.7561	4.7694	4.6847
	Services & Transport	4.8622	4.7561	4.7694	4.6847
	Construction	.6055	.6254	.6106	.7558
Year 2	Agriculture	0	0	0	0
	Equipment	1.0781	1.0842	1.0707	1.2069
	Consumer Goods	5.8017	5.8517	5.7655	6.6207
	Services & Transport	5.8017	5.8517	5.7655	6.6207
	Construction	.4472	.4628	.4496	.6754
Year 3	Agriculture	.2193	.2342	.2198	.2257
	Equipment	.7034	.7158	.6987	.8049
	Consumer Goods	1.0733	1.0911	1.0647	1.2903
	Services & Transport	.4834	.4805	.4771	.6059
	Construction	.2239	.2457	.2256	.2075
Year 4	Agriculture	.0284	.0323	.0286	.3934
	Equipment	.3403	.3499	.3372	.5810
	Consumer Goods	.1328	.1467	.1299	.2963
	Services & Transport	.3161	.3285	.3125	.1343
	Construction	0	0	0	.5810
Year 5	Agriculture	0	.0289	0	2.6251
	Equipment	.3961	.0836	.3891	4.3132
	Consumer Goods	.0168	0	.0113	3.9150
	Services & Transport	.3431	.3608	.3352	2.7170
	Construction	.0726	0	.0720	3.1672
Initial Constraints					
Year 1	Agriculture	0	0	0	0
	Equipment	0	0	0	0
	Consumer Goods	4.3130	4.2188	4.2307	4.1549
	Services & Transport	5.8114	5.6850	5.7007	5.6013
	Construction	0	0	0	0
Year 2	Agriculture	0	0	0	0
	Equipment	0	0	0	0
	Consumer Goods	3.9479	3.9904	3.9246	4.5719
	Services & Transport	6.0512	6.1039	6.0115	6.9261
	Construction	0	0	0	0

Production is bunched in the earlier periods with a 20% discount rate as compared to the results obtained for the 10% discount rate. This is to be expected, since a higher discount rate makes output produced at a later period less desirable.

Construction follows a peculiar pattern with a 20% discount rate. It produces at the minimum permissible level in the first two plan years, and then rises in the latter three years. A high discount rate increases the importance of earlier production. Thus, production is concentrated at the start in those areas where output can be quickly expanded. The construction industry is therefore completely neglected at this stage. Later, output in this sector is expanded to meet consumption and capital requirements for the post-plan years.

It is more difficult to compare shadow prices since the form of the objective function has changed with the change in discount rates. The structure of shadow prices, however, is the same as in the original solution. High shadow prices are registered in the first two years, especially in the consumer goods and services sectors. This reflects the initial capacity constraints. Agriculture has low or zero shadow prices throughout. Thus, we may say that a discount rate change alters the time phasing of production, but does not alter the basic priorities of the system.

The values of the objective functions of Cases 1, 2, 3, 5, 7, and 8, if arranged in descending order of magnitude, show the same ranking as in the original runs. We still find that redistribution in the rural sector gives higher values than those in the urban sector, and

that redistribution between the lower and middle groups yields higher values than those between upper and middle groups. The relative magnitude of gross outputs for the different runs maintain the same kind of position vis-a-vis each other as in the run with the 10% discount rate. The only difference seems to be a higher level of construction output in the first year for upper-middle income group equalization in the urban sector. This result is out of line with all other first-year construction figures, which are at the minimum permissible level with a 20% discount rate. This increase seems to have been obtained at the expense of agricultural output. Upper and middle class urban equalization actually imposes a tremendous strain on the system. This is illustrated by the very high shadow prices uniformly obtained under it, as compared to the other runs. The concentration of outputs in the early years because of the high discount rate invariably means that production has to take place in those sectors which require relatively less capital, so that maximum use can be made of initial capital stocks. This leads to the neglect of capital formation in the early years. In the case of urban upper-middle equalization, however, this would impose such a tremendous strain in the later years that a modest amount of capital formation has to take place even in the early years, to prevent infeasibility.

We could end by saying that, although changes in discount rates may change the time phasing of various sectoral outputs, the general nature of our results regarding the relative magnitude of the objective functions for different kinds of income redistribution schemes are insensitive to them.

Terminal capital stocks

The simulations are re-run assuming that post-terminal growth rates correspond to those laid out in the Draft Fifth Five Year Plan. Every one of these is infeasible. The introduction of zero foreign aid for the final year, and the explicit introduction of consumption requirements may be responsible for the resulting infeasibility. As mentioned earlier, the details of the exercises worked out by the planning authority are not available, and thus, one can merely guess at the possible reasons for the differences between our results and official plan projections. In order to keep post-terminal growth requirements in conformity with our present model, we put them equal to the average rate of growth of aggregate output over the plan years for the reference solution. This time, two of our cases are feasible. They correspond to the equalization of income between any two adjacent income groups in the rural sector. This seems to be a very powerful result. In order to produce efficiently, it may not only be desirable to redistribute rural incomes, but if modest post-terminal growth rates are postulated, it may be absolutely necessary to do so in order to avoid severe imbalances from showing up in the system. The values of the objective function obtained, it will also be noticed, are higher than that of the reference solution with no post-terminal growth stipulation.

We naturally obtain higher values of construction on the average with post-terminal growth requirements than without them. In agriculture, higher outputs are consistently obtained for runs made without any post-terminal growth requirements. In the other sectors, no clear dominance of

TABLE 15

Gross outputs with post-terminal growth requirements
(in million Rs.)

		Case 3	Case 7
Year 1	Agriculture	222570.6056	242399.6864
	Equipment	80066.0716	70467.6982
	Consumer Goods	75604.1300	75604.1300
	Services & Transport	153049.0500	153049.0500
	Construction	31185.2916	20374.2353
Year 2	Agriculture	224481.7244	283655.1423
	Equipment	85212.8200	63995.3744
	Consumer Goods	76485.1900	76435.1900
	Services & Transport	154775.3600	154775.3600
	Construction	29360.5942	15000.0000
Year 3	Agriculture	231415.4745	240422.6036
	Equipment	73438.6484	45390.5033
	Consumer Goods	64322.5809	63335.3731
	Services & Transport	170048.0935	170133.3465
	Construction	34820.3059	60865.7278
Year 4	Agriculture	236260.7975	242315.2861
	Equipment	55379.8426	15000.0000
	Consumer Goods	86363.0804	88257.8511
	Services & Transport	174486.5253	170317.6512
	Construction	36180.8712	62372.0347
Year 5	Agriculture	239720.3870	247181.7861
	Equipment	51357.8696	15000.0000
	Consumer Goods	89558.9235	95820.5541
	Services & Transport	178748.9012	157803.8432
	Construction	37959.0498	74905.7910
Value of objective function		2431249.4788	2419257.6007

TABLE 16

Shadow Prices with post-terminal growth requirements

		Case 3	Case 7
Year 1	Agriculture	.0203	.0398
	Equipment	.6048	.6155
	Consumer Goods	4.9206	4.9011
	Services & Transport	4.9206	4.9011
	Construction	.8240	.8497
Year 2	Agriculture	0	0
	Equipment	1.3470	1.3545
	Consumer Goods	7.5207	7.5082
	Services & Transport	7.5207	7.5082
	Construction	.7340	.6536
Year 3	Agriculture	.2040	.3476
	Equipment	.8620	.9334
	Consumer Goods	1.4120	1.4453
	Services & Transport	.6846	.5879
	Construction	.1528	.3836
Year 4	Agriculture	.3731	.0546
	Equipment	.5683	.4528
	Consumer Goods	.2046	.2185
	Services & Transport	.0965	.4528
	Construction	.5683	0
Year 5	Agriculture	.0247	.0951
	Equipment	.7254	.1982
	Consumer Goods	.2757	0
	Services & Transport	.7742	.4267
	Construction	0	0
Initial Constraints			
Year 1	Agriculture	0	0
	Equipment	0	0
	Consumer Goods	4.3470	4.3133
	Services & Transport	5.8873	5.8678
	Construction	0	0
Year 2	Agriculture	0	0
	Equipment	0	0
	Consumer Goods	5.2775	5.2458
	Services & Transport	7.9157	7.8696
	Construction	0	0

either type of run is noticeable. For upper middle class equalization, the higher construction output levels are attained by having a lower output of consumer goods in the final year of the plan. It is understandable that terminal growth requirements impose a stronger demand on construction than on equipment output, since the former works with a two year lag. Thus, output requirements of only the sixth year affect equipment output, but requirements of the sixth and seventh years affect construction output.

The shadow prices for upper-middle equalization for the two variants are almost identical. This leads us to suspect that the imposition of post-terminal growth requirements do not affect relative priorities. The feasibility obtained in this case is only possible because the rural middle class does not have a very high demand for services, and therefore output in this sector can be lowered in the final year in order to alleviate the strains on the system. The income groups lying between the rural upper and middle classes, however, does have a strong demand for services and therefore infeasibility results in the case which allows for adjusted consumption ratios.

In general, our results seem to be rather sensitive to terminal capital requirements. Even modest post-terminal growth requirements lead to infeasibilities in a majority of cases.

Several simulation runs were made in order to find out the specific post-terminal growth rate beyond which each type of redistribution scheme became infeasible. The results are tabulated in Table 17.

A rough comparison of the ranks of the various types of redis-

TABLE 17

Type of Redistribution	Post-Terminal Growth Rate (% per annum)	Value of Objective Function (in million Rs.)
Between Upper and Middle — Rural (Case 7)	3.4	2412062.4275
Between Lower and Middle — Rural (Case 3)	2.5	2421060.5047
Between Urban and Rural (Case 10)	.4	2425071.8743
Between Upper and Middle — Urban (Case 8)	.4	2413756.4532
Reference Solution (Case 1)	.3	2406583.1921
Between Lower and Middle — Rural and Urban (Case 2)	.2	2442194.8333
Between Lower and Middle — Urban (Case 5)	.2	2405749.8154
Between Lower and Middle — Urban (Adjusted Ratios) (Case 6)	.2	2401598.2499
Between Lower and Middle — Rural (Adjusted Ratios) (Case 4)	.1	2462825.8935
Between Upper and Middle — Urban (Adjusted Ratios) (Case 9)	0	2376675.5010

tribution schemes in Table 17 with those of Table 1 shows up several interesting differences. Redistribution between the upper and middle income groups is more conducive to higher post-terminal growth rates than those between the lower and middle income groups when considering unadjusted consumption patterns. These, therefore, occupy a relatively higher position in Table 17 than they did in Table 1, which had them arranged in

order of the magnitude of the value of their objective functions, assuming no post-terminal growth rate. Higher post-terminal growth rates require a greater amount of capital formation, and, therefore, a redistribution of income toward groups which demand commodities requiring substantial amounts of capital is desirable. If the lower income groups are beneficiaries of the redistribution schemes, then production of goods desired by them (namely agricultural products) has to increase as well as the production of capital goods for the future. If more manufactured products are demanded, however, increased capital formation could perform the dual function of providing them as well as providing for the future.*

Rural redistribution is again found to be more desirable than urban redistribution. We can therefore say that as provision for the future becomes more and more important, income redistribution schemes should still concentrate on the rural sector, but emphasis should be increasingly given toward the upper income groups in order to prevent infeasibility in the plan.

Exercises have also been done to find out how the value of the objective function diminishes when increasing post-terminal growth rates are assumed. These exercises have been done for Cases 7 and 3, since they are the only cases which have yielded growth rates sufficiently high for us to obtain several observations, with a 0.1% interval. The results are given in Table 18.

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* - The bigger capital base makes it possible to obtain greater quantities of capital to sustain higher post-terminal growth rates — a basic result of the Mahalanobis model (53).

TABLE 18

Post-terminal growth rate (% per annum)	Case 7 Objective Function (in million Rs.)	Case 3 Objective Function (in million Rs.)
0.1	2420395.2470	2436884.4617
0.2	2420292.5145	2436431.2525
0.3	2420182.7483	2435939.7263
0.4	2420078.6038	2435449.2902
0.5	2419975.6824	2434971.0692
0.6	2419874.0721	2434488.7011
0.7	2419773.8521	2434008.1618
0.8	2419665.3546	2433507.1786
0.9	2419559.0713	2432987.4239
1.0	2419458.5687	2432429.8185
1.1	2419359.5000	2431877.0128
1.2	2419256.7460	2431249.1439
1.3	2419146.1577	2430563.4489
1.4	2419041.1841	2429886.7620
1.5	2418937.6667	2429210.0207
1.6	2418832.8359	2428815.2904
1.7	2418728.3012	2427783.6106
1.8	2418621.0038	2427034.0464
1.9	2418520.1369	2426188.5821
2.0	2418414.1528	2425319.3551
2.1	2418032.7016	2424461.4547
2.2	2417822.1199	2423760.4969
2.3	2417192.4651	2422760.1121
2.4	2416751.4469	2421902.9530
2.5	2416298.4912	2421060.5047
2.6	2415872.1567	
2.7	2415417.9811	
2.8	2414956.7695	
2.9	2414501.9922	
3.0	2414042.5017	
3.1	2413568.1346	
3.2	2413109.7698	
3.3	2412622.9331	
3.4	2412062.4275	

The decline in the value of the objective function occurs at a steady pace with each 0.1% of increase in the post-terminal growth rate. However, there is a sharp increase in the rate of decline for Case 7 when rates of growth higher than 2% are considered. This is accompanied by an overall rise in the shadow prices, which reflects the fact that the constraints are becoming increasingly binding. If we look at the values of the slack variables, we find this occurs because the consumer goods constraint becomes binding with a post-terminal growth of 2.1%, whereas it is non-binding at a rate of 2.0%.

Table 19 shows the sectoral output levels obtained for Case 3 averaged over the five years, assuming various post-terminal growth rates. Table 20 shows the figures obtained for Case 7.

The average agricultural output for the maximum possible post-terminal growth rate is lower in both cases as compared to the case with a 0.1% post-terminal growth rate. However, the difference is more for Case 3 than for Case 7. This is primarily due to the fact that agricultural output has to be reduced drastically in the final years of the plan in order to have resources free to produce the necessary capital for the post-plan period (see Table 21). This reduction is not as great for Case 7 (see Table 22). This could be due to the fact that in the latter case, the terminal year gross output levels are lower than those for the former case. The post-terminal growth rate, therefore, puts less extra pressure on the system.

Equipment production, as expected, increases steadily as higher post-terminal growth rates are postulated.

TABLE 19

Case 3

Post-terminal growth rate	Agriculture	Equipment	Consumer Goods	Services & Transport	Con-struction
0.1	245367.4552	68517.3716	78417.2763	165578.3977	27716.4029
0.2	244581.8551	69297.1920	78339.3884	165315.5380	27933.8150
0.3	243864.7702	70304.6935	78335.5973	164982.4720	28143.9281
0.4	242534.3230	71330.0213	78339.2802	164639.0564	28352.8033
0.5	241536.8033	72314.3533	78341.3568	164321.8789	28549.2678
0.6	240545.8571	73298.2110	78332.9645	163991.5803	28760.6922
0.7	239535.7638	74297.5552	78334.7192	163657.4958	28970.4631
0.8	238507.3426	75321.3673	78330.1290	163321.7263	29176.6657
0.9	237205.3921	76209.9010	78326.3527	163159.1978	29618.0524
1.0	235479.7130	76909.6039	78322.0856	163254.4844	30412.8485
1.1	233775.1432	77600.7813	78315.5788	163348.4326	31199.4767
1.2	232774.6819	78212.0395	78308.0110	163393.3095	31391.1736
1.3	232542.2979	78739.8509	78310.1169	153386.7283	30924.4595
1.4	232321.1929	79239.6316	78301.8082	163378.4484	30487.8211
1.5	232095.1401	79747.9706	78302.3835	163370.9558	30036.5289
1.6	231938.3441	80244.1306	78300.2209	163352.7656	29530.7435
1.7	232280.8520	80552.7647	78247.7118	163259.9027	28745.7927
1.8	232655.4302	80386.3370	78191.8026	163186.4738	27947.6583
1.9	233161.3731	80676.8210	76113.4050	163408.8567	27121.8201
2.0	233684.3710	80512.2790	78031.4205	163637.1351	26272.4622
2.1	234204.5177	80354.6467	77953.6075	163863.4843	25420.0841
2.2	234487.7223	80278.7542	77803.1244	164023.5412	24940.6089
2.3	235220.4583	80045.6715	77792.0615	164308.1315	23755.0929
2.4	235733.8643	79889.9949	77712.0740	164536.3326	22912.8329
2.5	236246.2373	79736.8783	77632.2684	164754.2708	22076.6716

TABLE 20

Case 7

Post-Terminal growth rate	Agriculture	Equipment	Consumer Goods	Services & Transport	Con-struction
0.1	250873.8126	43638.9208	82008.5947	161430.1436	43495.3840
0.2	250902.4563	43487.1746	81818.1491	161411.3849	43786.0309
0.3	250938.6090	43323.9151	81613.5044	161390.9742	44093.6165
0.4	250966.9996	43170.2149	81420.5763	161372.0006	44388.6035
0.5	250992.1411	43018.9108	81230.5240	161353.4431	44681.6819
0.6	251020.3486	42868.8479	81042.1846	161334.8975	44969.2196
0.7	251048.4576	42720.7798	80856.3620	161316.5866	45252.6698
0.8	251049.0612	42560.4473	80655.1556	161296.7519	45559.4385
0.9	251114.5655	42402.2669	80456.8999	161276.9558	45856.9984
1.0	251142.3393	42253.8653	80270.6399	161258.6207	46141.4691
1.1	251170.0197	42107.5196	80086.9741	161240.5272	46421.7195
1.2	251197.6915	41969.6436	79898.5999	161215.1813	46704.1596
1.3	251225.6960	41869.3531	79702.8780	161164.8608	46978.4627
1.4	251258.3950	41773.4502	79515.8886	161116.4299	47235.2316
1.5	251286.2610	41679.3819	79332.3555	161069.1471	47491.0217
1.6	251314.0011	41584.1753	79146.5883	161021.3166	47750.3398
1.7	251341.6317	41489.2412	78961.3519	160973.6245	48008.9440
1.8	251369.1153	41391.8991	78771.3927	160924.7674	48274.9000
1.9	251396.5663	41300.2050	78592.5001	160878.6628	48523.9646
2.0	251431.5287	41203.1544	78403.3268	160829.5537	48782.0562
2.1	251176.3333	41517.9924	78401.5442	161186.5260	48289.4519
2.2	251096.6233	41583.5462	78289.9502	161296.6137	48250.0513
2.3	250614.7311	42529.7334	78437.5715	161811.8744	47010.1138
2.4	250324.8584	43164.8335	78460.8948	162074.7441	46290.7624
2.5	250034.5569	43813.8238	78482.1709	162343.7652	45551.2496
2.6	249758.6858	44413.8733	78495.6384	162594.1726	44877.2102
2.7	249460.7379	45062.5539	78516.2438	162863.4671	44145.6409
2.8	249157.6581	45721.7652	78537.5127	163137.0666	43402.3284
2.9	248859.8718	46369.0657	78556.6949	163406.1223	42673.3606
3.0	248557.2319	47029.2872	78580.1179	163679.6216	41927.1349
3.1	248253.0930	47703.4470	78598.9537	163959.9137	41162.7857
3.2	247948.5772	48362.2882	78622.6825	164232.8394	40420.3187
3.3	247630.4881	49044.8066	78636.6282	164518.1170	39658.2768
3.4	247302.6063	49654.8966	78539.3186	164799.8985	39065.8536

TABLE 21

Gross agricultural output
Case 3
(in million Rs.)

Post-terminal growth rate per annum (%)	Year 4	Year 5
0.1	242050.6418	247075.0927
0.2	241249.3385	244297.0366
0.3	240279.3103	240718.7842
0.4	239302.4145	237086.4326
0.5	238360.3313	233592.8591
0.6	237411.8871	230096.8346
0.7	236452.7210	226535.2158
0.8	235475.0033	222924.6936
0.9	234257.0316	218459.7270
1.0	232665.9636	212671.7334
1.1	231092.5604	206953.6535
1.2	230232.6713	203904.9754
1.3	230158.7299	203768.2109
1.4	230081.4342	203639.4947
1.5	230008.1128	203504.8523
1.6	229905.2225	203340.1233
1.7	229587.9865	202973.8148
1.8	229249.5961	202574.1612
1.9	228697.7455	201815.5131
2.0	228135.7324	201055.9252
2.1	227572.5013	200280.7997
2.2	227111.2439	199679.6471
2.3	226458.9054	198751.4716
2.4	225896.9410	197977.1482
2.5	225348.2573	197236.8280

TABLE 22

Gross agricultural output
Case 7
(in million Rs.)

Post-terminal growth rate per annum (%)	Year 4	Year 5
0.1	243972.8945	248273.9217
0.2	243823.0656	248173.7699
0.3	243667.4962	248086.4158
0.4	243515.0813	247982.5957
0.5	243362.0823	247869.6656
0.6	243213.7898	247770.1700
0.7	243067.7603	247673.0556
0.8	242909.8107	247568.5327
0.9	242759.5835	247485.7170
1.0	242612.8047	247386.8597
1.1	242468.3668	247290.4859
1.2	242316.0310	247190.1666
1.3	242144.7835	247087.4614
1.4	241987.1453	247011.7693
1.5	241828.1747	246921.5191
1.6	241666.8020	246828.4150
1.7	241505.8599	246735.4628
1.8	241339.9596	246636.9278
1.9	241185.2993	246550.0524
2.0	241027.7092	246480.5761
2.1	241052.9536	246523.0552
2.2	240969.4155	246495.2006
2.3	241062.0055	246683.2996
2.4	241040.5868	246783.5905
2.5	241023.1970	246909.8974
2.6	240995.6622	247000.6851
2.7	240969.8891	247097.2982
2.8	240943.5966	247194.2040
2.9	240916.5486	247289.3925
3.0	240892.4436	247389.0053
3.1	240869.7328	247511.7112
3.2	240843.3218	247601.3210
3.3	240806.7469	247688.6422
3.4	240662.1133	247646.7813

There is no pattern discernible in consumer goods and services production. Since these sectors cater mainly toward final consumption, production has to be held at a steady level throughout. They are also sectors which are constrained by the system more than the agricultural sector, as evidenced by their relative shadow prices. Sharp increases in output, therefore, cannot be obtained in these sectors with the same ease with which they are obtained in the agricultural sector.

In Table 20, we note a reversal in the direction of movement of all but one of the sectoral output figures when moving from a postulated growth rate of 2.0% to 2.1%. This is also accompanied by a drop in the value of the objective function which is sharper than before. As has been noted previously, this is caused by the consumer goods constraint for the fifth plan year, which had hitherto been non-binding, now becoming so. If we visualize the problem in an n-dimensional space, the solution has shifted from one corner to another of the feasible space, thus entailing some sharp changes in the values in the optimal solution.

Foreign exchange availability

The simulations are re-run assuming that the availability of foreign aid is a minimal amount. Instead of Rs. 5000 million of foreign aid being available in the first four years, it is assumed that only Rs. 500 million is available in each of those years. The values of the objective functions for the different runs are listed below in descending order of magnitude.

TABLE 23

Type of redistribution	Value of objective function (in million Rs.)
Case 4	2393705.9503
Case 2	2374285.7748
Case 3	2368664.5041
Case 10	2358505.4336
Case 1	2340008.5913
Case 5	2338683.3512
Case 7	2336814.2391
Case 6	2334632.1930
Cases 8 and 9 are infeasible.	

It will be noticed that the ranking of the values follows nearly the same pattern as in the original runs. The only difference is that Case 5 occupies a position two rungs higher on the ladder in the original run. This means that a redistribution policy aimed at equalizing upper and middle income groups in the rural sector becomes relatively more desirable when we have a higher availability of foreign exchange. This is due to the fact that income redistribution between the upper two groups leads to less savings and an increased demand for commodities which use the scarce foreign exchange resource. The availability of more foreign exchange relieves the strain at precisely those points where it is hardest felt. A similar result is obtained in the urban sector where redistribution between the upper two income groups is infeasible when foreign aid availability is cut, but becomes feasible when it is increased to the expected amount.

TABLE 24

Gross outputs for reference solution assuming lower foreign exchange availability (in million Rs.)

Year	Agriculture	Equipment	Consumer Goods	Services & Transport	Con-struction
1	224296.7209	74879.0112	75604.1300	153049.0500	20669.2921
2	245208.1019	75409.8063	76485.1900	154775.3600	15000.0000
3	224846.5871	66957.1346	66704.2560	166992.0246	35366.9148
4	226259.9926	54096.4897	84259.4127	168784.5181	29504.1816
5	230611.0400	51443.6087	85757.0747	171916.3909	30791.0077

Value of objective function: 2340008.5913

Shadow Prices

1	.0318	.6076	4.8794	4.8794	.8344
2	0	1.3409	7.4460	7.4460	.6961
3	.2606	.8831	1.4077	.8373	.2461
4	.2297	.5118	.1960	.2359	.3163
5	0	.5734	.0986	.5734	.0225

Initial Constraints

1	0	0	4.3008	5.8403	0
2	0	0	5.2073	7.8145	0

The figures obtained for the reference solution may be compared to those obtained assuming a lower availability of foreign aid. Gross output figures are understandably higher in the former case, but the pattern of production is the same. In fact, a study of the two sets of shadow prices shows that the figures approximate each other very closely. Thus, the task of identifying bottleneck sectors may be completed without paying any particular attention to the availability of foreign exchange in the plan period. This result of course holds if we allow foreign exchange availability to vary within reasonable limits. The bottleneck sectors could very well be different if we increase foreign exchange availability

to levels which are not realistic, given the present politico-economic conditions.

We could say, in summary, that our results are generally insensitive to changes in the availability of foreign exchange.

Variation in savings rates

Several runs are made assuming a higher savings rate and a lower availability of foreign aid. In these simulations, the availability of foreign aid is kept at Rs. 500 million over the first four years, but the average savings rate is increased from 15% to about 26%. This consists of a 15% savings rate for the middle income group and a 40% rate for the upper income group. The values of the objective functions are arranged in descending order of magnitude below.

TABLE 25

Type of redistribution	Value of objective function (in million Rs.)
Case 3	2705189.1164
Between all income groups (Rural only)	2684849.5551
Case 1	2673685.3969
Case 2	2647494.3444
Case 10	2632943.9939
Case 7	2629866.8848
Case 5	2619254.9882
Complete equality	2578470.0219
Between all income groups (urban only)	2567124.8158
Case 8	2565498.2814
Between all income groups (Rural and urban)	2547191.6429
Between upper and middle (Rural and urban)	2505686.2383

TABLE 26

Gross output (lower savings rates)
Case 1 (Reference Solution)
(in million Rs.)

Year	Agriculture	Equipment	Consumer Goods	Services & Transport	Con-struction
1	261280.2568	83323.5700	72980.4284	153049.0500	45770.4588
2	303108.4795	85212.8200	72455.1928	154775.3600	15000.0000
3	292632.2558	60934.4073	75583.1107	172833.3326	49576.5471
4	295489.2036	62446.2849	77716.5323	174405.0987	40000.0000
5	313069.4700	60000.0000	78877.6054	177379.5350	40000.0000

No simulation runs are made allowing for the adjustment of consumption patterns. The biggest change noticeable in these figures as compared to the ones obtained formerly is that the complete equalization of income between all income groups is feasible, and also leads to a high value of the objective function in the case of rural redistribution. Complete equalization of income, given the pattern of income distribution in India, implies that income is taken away from the upper groups and given to the lower group, while the middle class remains in approximately the same position as before. Assuming unchanging patterns of consumption, this implies that the overall savings rate is drastically reduced. The higher savings rates assumed in these runs corrects this, and the less demanding consumption pattern of the lower income groups ensures a high value of the objective function. We still find that redistribution between the lower and middle groups leads to higher outputs than redistribution between the

TABLE 27

Shadow Prices for Reference Solution (lower savings rates)

Year	Agriculture	Equipment	Consumer goods	Services & Transport	Construction	Foreign Exchange
1	0	1.4530	.0241	6.1966	.6955	6.1966
2	0	2.0962	1.2190	10.0183	.5019	10.0183
3	0	1.2725	.5628	1.2960	.1701	1.2725
4	0	.7051	.1200	.6261	0	.7051
5	0	1.1052	.4213	1.1052	0	1.1052
Initial Constraints						
1	0	1.0133	0	8.6286	0	
2	0	.5765	0	11.2176	0	

redistribution leads to higher gross outputs than urban income redistribution.

7. Policy implications

It is obvious at this stage that any plan for redistribution requires a lot of thought and very judicious planning on all economic fronts. It also needs a very careful treading of the line so that economic objectives do not run afoul of political realities. A very important determinant of the latter are the political institutions which determine the structure of government. The history of the past twenty-eight years has been one of attempting to reconcile acceptable economic objectives with the existing political framework. However, the appropriate political structure is defined by the objective of the country. The Indian one, patterned as it has been on the British example, is necessarily geared to a society whose attitudes and mores are similar to the latter. The British system, based as it is on the philosophy of Locke, puts fundamental importance on the inalienable rights of private property. This, however, sharply clashes with the prevailing Indian viewpoint that economic inequalitites are too great and too widespread to be reconcilable with any concept of justice or fairness. These differentials, it is generally agreed, have to be reduced.

The question is not whether any redistribution of economic power should take place, but in what manner it should be carried through. The economic framework is a very complicated one with complex patterns of

inter-relatedness which are difficult, if no impossible, to unscramble without technical help. Any new economic policy has repercussions which are felt throughout the economy. Before a policy is put into operation, therefore, a thorough study of these effects have to be made, and subsidiary policies formulated to take care of any problem areas, so that a smooth transition can take place. The accurate anticipation of these pressure points facilitates the proper tackling of these problems when they arise. In economic maladies, as elsewhere, precautionary measures are much more efficient than cures devised after the disease has set in. The above could also explain why the Indian government has not been able to come out with a policy to eliminate inequalities despite the socialistic platitudes emphasized in political statements. More than a proficiency in oratory is required to become an efficient and plausible Robin Hood.

Among the different types of redistribution policies considered, we find that rural redistribution measures make far less demands on the economy than do urban ones. This is both surprising and gives room for optimism. The surprising nature of the result arises from the fact that the rural sector is by far the larger part of the economy. We would therefore expect changes made in that sector to have a greater impact on national figures than changes made in the urban sector. The nature of consumer demand in the rural sector is, however, such that no undue demands are made on the weaker segments of the economy. The result is cheering because the rural lower class is the most poverty stricken in the entire economy, and most redistribution schemes are aimed at bettering their lot. It seems, therefore, that this kind of redistribution scheme could be profit-

ably implemented without putting any undue pressure on the economy; in fact, in the context of our model, there would actually be an increase in the sum of discounted values of gross outputs over the five plan years!

Urban redistribution schemes invariably exert a lot of pressure on the manufacturing sectors in the early years. In order to have a successful redistribution policy on this front, one must have an economy which is much more controlled than the Indian economy is at present. In such cases, the problem of meeting the urban consumer's demand for manufactured consumables could be tackled by simply not meeting his demand in the initial years, so that agricultural shortages would not arise later. The question of whether such controls will be acceptable to the people is not an economic or political one, but rather a sociological one. The proper dissemination of information could make the process easier, especially if we consider the fact that the urban population is more literate and knowledgeable than the rural population.

The key to an explanation of the solutions obtained is that agricultural production, contrary to popular opinion, is not the stumbling block to redistribution and growth. The agricultural problem is undoubtedly one of epic proportions — the problems are those of grain requisitioning, marketing, tenural conditions and rural indebtedness, but not of overall production. This is, of course, not to deny that agricultural productivity could be made higher if the problems mentioned are solved.

To understand the agricultural problem, we must study the pattern

of land holding in India as well as the tenural conditions that prevail. A study of the latter is in itself very involved as there is a complicated pattern of tenural relationships in India. To simplify matters, we may note that the lower income agriculturist has one of two choices, i.e., either he may rent land from the higher income groups and cultivate it for himself, or he may be employed as a hired laborer on land belonging to someone from the upper income group. In either case, he finds himself obligated to the landlord. In the former case, he needs help from the landlord to sustain himself until his crop can be harvested. The loan that he obtains from the landlord is fixed in monetary terms at a time when agricultural prices are high. When it is repaid after the harvest, agricultural prices are low, and so in effect the landlord gets back in real terms a far greater volume of the crop than he lends out. This part of the crop also does not appear in the landlords official grain output figures, and so cannot be requisitioned. It can therefore be hoarded, thus creating an artificial scarcity of agricultural commodities (7). In the case of hired labor, too, the very low wages force the lower income worker into loans obtained from his landlord. These loans are normally made in kind, but the repayment obligation is fixed in money terms. Again, after the harvest, the laborer is forced to pay back a far larger amount in real terms, and again the output does not appear in official figures, since it is repayment of a loan, and therefore not subject to requisitioning.

The problem of rural indebtedness, harsh tenure conditions, and inequalities of income are all interlinked. A solution will have to

solve them simultaneously. We do know from our simulation runs that redistribution of rural incomes will not pose any undue problems as far as intersectoral balances are concerned. We also know that the rural upper class is politically a very powerful group. It would therefore seem to be a good idea to subsidize the rural middle class in order to build up a strong counter to the upper class, at the same time making these subsidies available conditional to their affording to the lower class certain basic minimum wages and amenities. The subsidies could be based on the number of people employed or the amount of land used. This, in effect, redistributes income from the upper to the lower two classes. In this manner, we could equalize the rural income differential, which is desirable, raise the standard of living of the rural poor, which is absolutely necessary, and also build up a strong political counter to the rural upper class which is needed to reconcile economic objectives with political realities.

The sensitivity tests undertaken reinforce the point that steps have to be taken on the rural front to even out inequalities in income distribution. The value of the objective function is found to be consistently higher for rural redistribution schemes, for each and every kind of parameter variation. As higher post-terminal growth rates are postulated, redistribution between the upper two income groups becomes increasingly important, since all other schemes lead to infeasibility. In fact, if any growth rate higher than 2.5% per annum is desired, it is essential to redistribute incomes between the two upper rural income groups to obtain feasibility. This is in line with our recommendation of building

up a strong rural middle class. Further redistribution toward the lower classes is desirable in that demand is directed away from the scarce sectors, but could pose problems in the form of a lower savings rate. We therefore find that redistribution between the two lower rural classes always leads to a higher value of the objective function than redistribution between the two upper classes, but infeasibility is obtained at a much lower post-terminal rate of growth (2.6% as against 3.5%). The inclusion of the rural lower class in redistribution schemes (which is necessary for extra-economic reasons) should, therefore, be accompanied by schemes to raise the savings rate among the other classes in order to obtain at least a 3% per annum growth rate in the post-terminal period.

In order to obtain any realistic post-terminal growth rate, it is necessary to assume that consumption patterns do not change as each group's income level changes. If they are allowed to adjust, we do not obtain feasibilities with any meaningful post-terminal growth rate. The influencing of consumer behavior patterns is rather a difficult task for any policymaker. One way of tackling the problem could be by giving lower income groups an increasing portion of the extra income obtained through redistribution in kind. This would, in a sense, force the consumers to retain their old pattern of consumption. It would, of course, involve the authorities in a substantial amount of quantity planning, an issue to which we turn later.

We also note that the shadow price of foreign exchange, although rather high at the beginning of the plan, falls very sharply from the third year onward, no matter which simulation run we consider. This

implies that India's objective of being independent of foreign aid is not only realizable, but that an extra rupee of foreign exchange will really not add much to the value of the objective function by the end of the plan. An extra rupee of foreign exchange adds more than six rupees to the value of the objective function in the first year, but adds barely a rupee in the final year. This implies too that for optimal growth, the pattern of production has to change during these five years to make foreign exchange less valuable than before. We find, too, that independence from foreign aid is not only politically desirable, but also economically feasible.

The question now arises as to the kind of planning framework that the economy must possess in order to implement policies. If total quantity planning can be practised, we can neglect the effects of market prices on consumer demand. The planning authority fixes all production targets and distributes output in the way it deems fit. Thus, production is fixed at the level which maximizes the objective function. If the planner now wants to allow the consumer to engage in market transactions, he can post the list of shadow prices at which commodities are to be sold, and distribute the income appropriately. Given the fact that consumption responds only to income changes, the appropriate distribution of income will ensure that the total product supplied for consumption purposes is equal to the quantity demanded by households at the corresponding shadow prices. Market prices are then equal to shadow prices by fiat, and equilibrium is achieved, given the structure of the model.

If a perfectly competitive system works on the other hand,

shadow prices have to be necessarily equal to market prices by the Lange-Lerner theorem (48, 50). In such a case, the government has to merely redistribute income by some sort of tax-cum-subsidy scheme, and production will take place in the most efficient manner. The actual production figures will not be identical to the ones obtained in our runs if we allow consumption patterns to change in response to relative price changes. If shortages arise in a particular sector in a particular year because of a particular kind of redistribution policy, market prices will rise, causing consumers to change their consumption patterns. In general, demand will move away from that sector to others. This will lessen the pressures on that sector, and lead to higher values of the objective function. Market prices will not rise as much as the shadow prices, which are derived on the basis of a fixed coefficient consumption pattern. The general import of our results will, therefore, remain the same, the smooth substitutions allowing the economy to reach higher output levels with less price fluctuations.

The actual Indian case falls between the two extremes discussed in the previous paragraph. The Industrial Policy Resolutions have classified industries into three groups. The group of basic industries is totally controlled by the government. An intermediate group of industries allows both the public and private sectors to co-exist. The third group, consisting mainly of consumer goods, allows private participation. In terms of our model, it is as though the government undertakes quantitative planning for some of the sectors, leaving private enterprise to take care of the rest. We may assume that the government sets production

targets for the capital-producing sectors, while leaving the output decisions in the other three to private producers. The working of the free enterprise system in these sectors allows for consumption patterns to adjust to market prices. This again smooths out potential bottleneck areas, and should lead to higher values in the objective function than those obtained in our runs.

In closing, we may note that India seems to be approximating total quantity planning to an increasing extent. Since monopoly elements are fairly strong in India, the change to quantity planning should lead to higher output levels than those obtained under free enterprise. This strengthens our case for implementing rural redistirbution schemes.

CHAPTER 6

Conclusion

We have considered the effects of alternative distributions of income on the optimal pattern of resource allocation and gross outputs in the Indian economy. Two distinct types of income distribution are usually considered by the theoretical literature on income distribution. One distinguishes between returns to different types of factors of production, e.g., labor, capital. The other distinguishes between different classes of income earners, e.g., laborers, capitalists, etc. For our exercises, we do not use either of these concepts. We consider the size distribution of income, which differentiates income earners on the basis of the size of the income that they earn. This seems more relevant for a country which is committed to a socialist pattern of society, and circumvents the problems involved in working out a correspondence between the size distribution of income and the type of income earned.

Claims have often been made that a redistribution of income, while desirable as such, leads to a lower rate of savings, and thus slows down the rate of growth. There is, however, another side to the picture. The redistribution of income changes the pattern of final demand, since different income groups have differing consumption patterns. If redistribution schemes result in a diversion of demand away from products which are relatively scarce to those which are relatively abundant, we can still derive some benefit from these schemes. The overall effect then depends upon the relative magnitudes of these two opposing effects, and cannot be

determined unless an intersectoral, intertemporal model is worked through in detail. This we proceeded to do.

The results obtained have been rather interesting. Certain types of redistribution schemes, we find, do indeed result in higher gross outputs over the plan than what is obtained assuming the status quo distribution of income. Other schemes yield lower values, and some are infeasible.

In general, higher gross outputs are obtained for rural redistribution schemes, and for redistribution between the lower and middle income groups. Alternatively, we find that urban redistribution schemes yield consistently lower values, and the same is true for redistribution between the two upper income groups. In most of these latter cases, the value of the objective function is lower than that obtained in the reference solution.

The exercises worked out above assume that consumers retain their old pattern of consumption after the income redistribution takes place. This may be justified by noting that spending habits usually take time to change, and we are considering only a five-year horizon. We also alternatively assume that consumption patterns change instantaneously with changes in income levels brought about by the redistribution schemes. Rural redistribution and redistribution between the two lower income groups still lead to higher values of the objective function than urban redistribution and redistribution between the two upper income groups. However, when comparisons are made of the solutions obtained under the alternative assumptions of consumption pattern adjustment, we do not find either of these assumptions consistently leading to higher values of the objective

function. Thus, for 'lower-middle' class redistribution in the rural sector, we obtain higher values of the objective function when we assume that consumption patterns can adjust instantaneously; however, for 'upper-middle' class redistribution in the same sector, a higher value is obtained when we assume that households retain their old consumption patterns.

The crux of the matter seems to lie in determining the exact point on the income scale where the demonstration effect sets in. As we start giving lower income groups higher incomes, the overall savings rate goes down, but at the same time demand is diverted toward the less scarce agricultural sector. The demonstration effect has not set in. When these schemes are implemented for higher income groups, demand is diverted toward the scarcer manufactured consumer goods sector because of the demonstration effect, and consequently greater strains are felt on the system. The demonstration effect, it has been noted, sets in at a higher income level in the rural sector as compared to the urban. This is to be expected as urban groups are more exposed to the consumption behavior of people belonging to other income classes than are rural groups. It is also seen that when the demonstration effect does come into effect in the rural sector, the increased demand is directed more toward services than toward manufactured consumer goods, as was the case in the urban sector. The conspicuous consumption of the rural landlords has been noted in Indian economic history books, and portrayed vividly, and sometimes dramatically, in Indian literature. The need to redistribute rural incomes is the message which emerges most clearly from these exercises.

The results have been obtained given certain values for the

parameters of the model. Sensitivity tests are made to find out whether the results hold when some of the parameters are changed. We find that the solutions are extremely insensitive to changes in the value of the social discount rate. This result has been noted in the earlier study done by Chakravarty and Lefeber (19).

The posing of modest post-terminal growth rates lead to infeasibilities in all the cases, barring the two cases of rural redistribution run under the assumption of unchanging consumption patterns for households. It seems, therefore, that rural redistribution is not only desirable, but essential for the successful completion of the Fifth Plan. The existing distribution of income allows a maximum attainable post-terminal growth rate of only 0.3% per annum, a rate which is far below that of the projected population increase. The suggestions for income redistribution given in the Fifth Plan, therefore, should not be looked upon as just tentative recommendations, but as an essential part of the plan program itself, which has to be necessarily fulfilled if the plan is to succeed.

If consumption patterns are allowed to adjust instantaneously even these rural schemes are infeasible. It is essential, therefore, to derive policies which delay the adjustment of consumer behavior of households. This could be done by government advertisement campaigns advising against certain types of consumption. Redistribution schemes can also be implemented in kind or on some kind of coupon system, the coupons being redeemable only in certain specific commodities. Finally, the government may have to resort to quantity planning in the scarce commodities, if the other schemes fail.

The availability of less foreign exchange makes redistribution between the upper and middle classes less desirable. This is to be expected, since the middle income group demands commodities which use a relatively greater amount of foreign exchange than the lower income group. The curtailment of foreign aid, therefore, results in greater strains on the system in the case of redistribution between the two upper income groups. Consequently, the value of the objective function is lower.

Finally, we vary the savings rate. If we assume the average savings rate for the entire population to be as high as the actual overall marginal savings rate, the complete equalization of all incomes is feasible. The cases which were feasible before at the lower savings rate maintain their relative rankings when arranged in order of the magnitude of their objective functions. We can still say that rural redistribution between the lower and middle income groups is preferable to any other kind of redistribution. Our conclusions, therefore, are general in nature, and not dependent upon any particular set of values chosen for the social discount rate, the level of foreign aid, or the savings rate.

Suggestions for further research: Several innovative exercises come to mind, but they can be conducted only after the required types of data become available. In fact, therefore, the next step in studies relating to Indian income distribution can very well be in the field of statistical data collection.

An important limitation in our study has been the non-identification of our income groups with the function that they perform as factors of production. Thus, we do not know what proportion of income earned by each

group is wages, profits, etc. We also do not have the occupational distribution of the people in each income group. If this kind of data is available, action can be taken on the production side to bring about a more equitable distribution of income. As it stands now, we have to resort to some kind of tax cum subsidy program to take incomes away from richer households to give to poorer households. The latter may be politically more difficult to implement. The collection of the appropriate type of data can enable us to conduct our exercises on the basis of the functional distribution of income. Suitable wage-price policies can then bring about the desired change in income distribution.

A great deal of work needs to be done in estimating the depreciation of different types of capital equipment. This is extremely relevant for an economy which is modernizing very rapidly, thus making obsolescence a very important factor in the calculation. Unfortunately, the data available on this score is negligible. The models on India which do include depreciation, admit to a great deal of arbitrariness in their depreciation calculations. None of them, to my knowledge, have really tackled the problem of obsolescence, and the fact that a machine today may have a shorter life span than a machine which performed the same function twenty years ago should be taken into account in such calculations. Otherwise, biased results may be obtained.

Several macroeconomic models have been built for India. However, there is a dearth of regional models. This is a serious shortcoming since the macroeconomic models tend to gloss over local problems in a country which is as large as India. The collection of data for these local models

is also likely to be relatively easier than that for the whole country, since the problems of coordinating different types of data sources for the national models are great. More attention should therefore be paid to developing such models.

To sum up, we have been considering various ways in which to share the economic pie, and how this affects the size of the pie. Current economic thinking assumes very often that the major problem lies in ensuring that the pie is large enough — the sharing of it being a trivial detail which may be pushed to the background. It is also often thought that a preoccupation with the division of the pie may actually result in a smaller one than could be obtained otherwise. We have tried to make the point that the problem of sharing is a very important one in its own right. Moreover, if the right type of distribution policy is followed, we will end up with a bigger pie than can otherwise be obtained. It is hoped that these results will whet the appetites of people for such policies.