SOME EXPERIMENTS WITH A MULTISECTORAL INTERTEMPORAL OPTIMIZATION MODEL FOR SRI LANKA

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Summary

In this study a Multisectoral Intertemporal Optimization model is posited and used to study the optimal development path for Sri Lanka (under certain conditions and assumptions) so as to attempt to identify the binding constraints for the country's development. Experiments are carried out on the model to examine the relative importance of domestic savings and foreign exchange and also to highlight the distributional implications of economic development along the optimal path. In addition an attempt is made to examine the use of formal techniques for planning the sectoral and temporal allocation of resources for development through an investigation of the feasibility of Sri Lanka's Public Investment Programme 1980-1984.

Economy-wide development planning models of an optimization nature have mostly been concerned with the optimization of a single objective such as consumption or income. However, development planning can better be considered as a problem of decision making with multiple objectives. Yet, no attempt has been made to analyse the multiple objective situation formally, except for a few analytical models of dual economy which took the distributional objective into account. In this respect, the present study represents an improvement over the existing models. First, considering only the two objectives of consumption and its distribution, a social welfare function is specified and used as the objective function of the optimization model, and second, recent developments in Multiple Objective Decision methods are employed to resolve the problem imposed by the multiplicity of objectives.

The results of the experiments shed reasonable doubt on the feasibility of the Public Investment Programme 1980-1984. It is shown that the importance of additional domestic savings is limited as the economic development of Sri Lanka is highly constrained by the lack of foreign exchange. It also is shown that on an optimal path of development, objectives of economic growth and distribution are not conflicting; development along an optimal path does not change the relative income shares of the rich and the poor substantially. It is suggested that fiscal measures can be used to improve the income share of the poor and pointed out that such measures do not conflict with economic growth.

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Declaration

I declare that this thesis is based on original research carried out by me and that the research material has not been published elsewhere nor presented to any other institution. Research work of other authors whenever used or referred to have been duly acknowledged.

CHAPTER 1.

INTRODUCTION.

In this study a Multisectoral Intertemporal Optimization model is posited and used to study the optimal development path for Sri Lanka (under certain conditions and assumptions) so as to attempt to identify the binding constraints for the country's development. A multiplicity of development objectives can be incorporated into the optimization model. This multiplicity of objectives can create certain problems and various methods are investigated to overcome them. Experiments are carried out on the model, to examine the relative importance of domestic savings and foreign exchange and also to highlight the distributional implications of economic development along the optimal development path.

The aims of this introductory chapter are, first, to introduce the basic features and problems of Sri Lankan economy which have a direct bearing on the model design, and secondly, to introduce the nature and scope of the study in more detail.

1.1 Basic Features and Problems of the Economy of Sri Lanka.

Sri Lanka has been rated highly among developing countries on her achievements in the field of social welfare. It is well-known that she has been a forerunner in the provision of social welfare. Sri Lanka has a system of free education and health services and consumer subsidies which is unmatched anywhere in the South Asia.[1] Successive Governments in Sri Lanka have been committed to continuing a policy of providing extensive welfare services. According to one writer,[2] Sri Lanka occupies a unique position in the world economy because, except for a few countries such as Sweden, the welfare services experienced by Sri Lanka continuously since independence in 1948 are unparalleled. This scheme of social welfare services has achieved its intended effects of raising the health and educational standard of the community and improving the living standard and distribution of incomes.[3] However, there has not been a significant increase in the productive capacity and the slow rate of growth in output has imposed a formidable constraint on the country's ability to actively pursue its welfare services.[4]

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1. Jones and Selvaratnam (1972 pi).
2. Karunatilake (1975).
3. "Sri Lanka has an exceptionally good record in relation to its per capita income, on life expectancy, infant mortality, fertility and literacy ..... In each case Sri Lanka's social indicators relative to its income, were the best among 59 countries". Isenman (1980 p.239). According to Ahluwalia et al (1979), Sri Lanka was the only country of the thirty six countries for which data were available where the marginal share of income accuring to the bottom 60% of the population (between 1963 and 1973 in the case of Sri Lanka) was higher than 50%.
4. Isenman (1980 pp. 245-246).

In 1980 the Gross National Product (GNP) of Sri Lanka was an estimated Rs 61814 million at current factor cost prices[1]. With a population of 14738 thousand, this represents a per capita income of only Rs 4194, that is £108. By any standard, this level of income is low, particularly as real (at 1970 prices) GNP in 1980 was only Rs 19405 million which represents a per capita income of only Rs 1317, that is only £59.[2] In the period 1970 to 1980, real GNP grew at an average annual rate of 4.33% while the population grew at an average annual rate of 1.65%, representing only 2.68% average annual growth rate in per capita real GNP. This rate was highly affected by the relatively rapid developments in the economy after the introduction of new economic policies in November 1977.[3] Until 1978, growth rate was even lower, in the period 1970-77, the average annual rate of growth in per capita real GNP was only 1.49%. The growth performance of Sri Lanka, particularly until 1978, has really been a disappointment. As Morawetz (1980) reported, in the period 1950-75, per capita real GNP grew only at an average annual rate of 1.6% which is well below the average annual growth rate of 3.0% recorded for all developing countries[4] as a whole.

Under the British rule, export-oriented plantation agriculture was introduced into the Sri Lankan economy and ever since it has been an economy dependant on the rest of the world. As a dependant economy it

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1. Data referred to in this chapter are, unless mentioned otherwise, those estimated by the Central Bank of Ceylon and published in its Annual Reports and Review of the Economy.
2. This is at the exchange rate implicit under the Foreign Exchange Entitlement Certificate Scheme in 1970, which was 55% higher than the official parity rate.
3. See section 1.2 of this chapter.
4. Excluding China.

has high ratios of exports and imports to Gross Domestic Product (GDP). As Dahanayake (1977 p.10) has reported the export share of GDP in 1950 was 38.1% and has tended to decline over time, largely due to the absence of any significant growth of export earnings of the country. This share dropped to 22.33% in 1972, but gradually improved up to 33.81% by 1977 reflecting largely the favourable prices received for the main export commodities.

The Sri Lankan economy highly depends upon three primary commodities, tea, rubber and coconuts, for its foreign exchange earnings. In 1970, more than 88% of the total commodity exports were from these three major exports. In recent years, there seems to have been a tendency for the share of these major exports to decline. In 1977 it was 74.27% and declined to 57.85% by 1980. However, it is still a substantial share and therefore the economy has to depend quite highly on these three major exports. Yet, the development of these three commodities is rather disappointing. The volume of exports of these commodities has tended to decline, even though there has been some improvement in prices since early 1970's. In recent years the export of industrial products seems to have grown at a relatively higher rate. Their share of total commodity exports rose to 31.82% in 1980 compared to 14.18% in 1977. However, a large portion of this consists of Textiles and Garments (10.50%), and Petroleum products (17.36%). It is a good sign that the economy is diversifying its exports and reducing the dependency on three major exports. Yet net foreign exchange earnings from the exports of textiles and garments and petroleum products could be very low, as their import content is substantially high.[1)]

Slow growth in export earnings represents a formidable problem for Sri Lankan economy as it restricts the import capacity of the country. The economy depends on imports not only for its requirements of intermediate and investment goods but also for essential consumer goods. High dependency on imports is evidenced by a high ratio of imports to GDP. After the mid fifties the import ratio has tended to exceed the export ratio of the economy. In the 1970's it was only in 1977 that the import ratio fell below the export ratio.[2)] Since 1977 with the liberalization of imports, the ratio of imports has been increasing substantially, with a very high ratio of 55.07% in 1980 compared to exports ratio of 32.69%.

An important feature in Sri Lanka's imports has been the high proportion of consumer goods in total commodity imports. In the period 1970-75, with the exception of 1974, consumer goods formed more than 50% of the total commodity imports; and of these consumer goods, three main foodstuffs - rice, flour and sugar - alone amounted to more than one quarter of the total commodity imports. Since 1978, the share of consumer goods has been declining thereby representing higher shares of intermediate and investment goods. In 1980, the share of consumer goods

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1. "... in view of high prices to be paid for crude oil imports, the net foreign exchange gain from bunkering and naphtha exports are not that conspicuous in relation to gross earnings from such exports. Similar situation prevails with respect to the exports of textiles and garments whose imports content is substantial." Central Bank of Ceylon (1980 p.152).

2. This was largely due to the improved exports earnings in that year, resulting from the higher prices of tea and rubber.

was 29.4% of which rice, flour and sugar was 13.2%. This recent tendency is not due to a reduction in the expenditure of consumer goods imports, but is due to the increases in imports of intermediate and investment goods. Rationalization of the consumer subsidy programme made it possible to keep the growth of imports of consumer goods at a lower rate, while the increased level of economic activity recorded under the new economic policies required a high growth in imports of intermediate and investment goods.

As the economy is so highly dependent on imports, it is vulnerable to the movements in international commodity prices. Since 1955 - until about 1972, there had been a steady downward trend in both tea and rubber prices while the import prices continued to rise, leading to a massive deterioration in the terms of trade. Since about 1972, there has been a significant rise in the prices of Sri Lanka's major exports, but it has been followed by a sharp rise in the prices of essential imports, underlining the vulnerability of Sri Lankan economy to the developments in commodity market. The termsof trade (with 1978 = 100) fell to 57 in 1975 compared to 94 in 1972; it improved to 101 in 1977 but fell steadily to 58 in 1980.

Slow growth in export earnings relative to the expenditures on imports caused balance of payment difficulties which has been a major problem for the economy since the late 1950's. Since 1957, the current account of the balance of payments has been in deficit except only in 1965 and 1977. Reactions to the balance of payment difficulties had been to take measures to restrict imports. Import licensing was introduced in 1962 and was made progressively more and more restrictive, introducing quota restrictions and a complete ban on imports of certain luxury goods. These controls prevailed until the liberalization of imports in November 1977. The controls had been successful in restricting imports in the aggregate, but it caused a significant deterioration in the standards of consumption and by restricting the availability of intermediate imports hindered the development of manufacturing industries, despite the incentives associated with higher level of protection.

As pointed out in Pyatt et al (1973 pp. 31-32) Sri Lanka's social welfare programme interacted with the balance of payment position in three ways. First by depressing the incentives for increased food production it contributed to a large import bill for basic foodstuffs. Second, by diverting investment into projects with long construction period and low productive returns, e.g. schools, it slowed the expansion of manufacturing output. Finally by boosting real incomes, the welfare programme generated an 'artificially' high level of demand for consumer goods which reacted back in balance of payments.

In the face of these balance of payments difficulties, the economy could not maintain a reasonable level of investment and domestic savings. In the period 1970-77, although the ratio of investment to GDP had been fluctuating it remained low. It was 18.95% in 1970 but dropped to 13.74% in 1973 and gradually rose to 16.21% in 1976. It was 14.45% in 1977, but since 1978 it has been increasing steadily recording 35.70% in 1980. The ratio of savings to GDP has also been fluctuating over the same period but it has remained well below the investment ratio, except in the years 1965 and 1977 when the current account of the balance of payment was in surplus. In 1980, the savings ratio was 13.41% compared to 14.18% in 1970. Even though the investment ratio has been increasing since 1978, there has been no improvement in the savings ratio in spite of the fact that Sri Lanka has made genuine attempts to raise the level of savings. In order to encourage savings, the branch net work of the commercial banks was expanded and the National Savings Bank was established in 1972 which amalgamated the functions of a number of small savings institutions. Interest rates were raised in 1972, 1977 and again in 1980.

The effects of the low ratio of investment and savings were reflected in slow rate of growth in output and high rate of unemployment in the labour force.

Unemployment has been a continuing problem in the economy since the late 1950's. Between 1963 and 1973, the estimated unemployment rate in the workforce increased from 13.8% to 24.0%.[1]
These estimates simply indicate the magnitude
of the problem. Preliminary data of the Consumer Finance and Socio-Economic Survey of 1978 indicated a drop in unemployment rate to 15.3%,[2] yet this still is a substantial rate and therefore unemployment remains a critical problem in the economy. A high level of public expenditure on education has compounded the problem by making the labour force highly

1. Central Bank of Ceylon (1964, 1974).
2. Central Bank of Ceylon (1979a p.41).

educated while the developments in the economy were not sufficient to absorb it, thus creating a high rate of unemployment among educated people.[1)]

To sum up, Sri Lanka has managed to achieve a remarkable position in the field of social welfare without a reasonable growth in real national product. Therefore there has been a failure to resolve the interrelated problems of balance of payments and unemployment.

1.2 Economic Policy Reforms in 1977.

Until late 1977, economic policies pursued by Sri Lanka were mostly inward looking and socialist oriented.[2)] Maintenance of social welfare services received high priority, and therefore in the interest of consumers, prices of a number of commodities were controlled and prices of imported goods were kept artificially low by maintaining an overvalued exchange rate. An overvalued exchange rate implies that exports were discouraged. However, cheap imports could not be made freely available because the availability of foreign exchange was limited. Therefore an excessive system of import and exchange controls was imposed. The final outcome of this, as Dahanayake (1979 p. 36) pointed out, was a misallocation of resources as the prospective industrialists had to either lobby and bribe for their quotas or abandon new investments.

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1. e.g. In 1973 the estimated rate of unemployment among those with G.C.E. (O.L.) was 47.4% and that with G.C.E. (A.L.) was 44.4%. Respective figures in 1978 was 29.2% and 31.7% - see Central Bank of Ceylon (1979 p. 42 Table 1.15).

2. See Dahanayake (1977) for a review of economic policies in the period 1956-72. There was not any major change in economic policies until late 1977.

The present government which came into power in July 1977, introduced a package of policies in November 1977, which could be considered as growth and employment oriented. This policy package included:[1)]

- freeing the economy from most of the controls that prevailed earlier, in order to promote competition and ensure efficiency in resource allocation and production, i.e.
    i. the liberalization of imports and payments
    ii. the lifting of price controls and greater reliance on the market mechanism
    iii. the removal of excessive administrative controls
- floating of the exchange rate
- extensive incentives to foreign and local private capital to participate in domestic investment
- rationalization of consumer subsidy programme to confine subsidies to the low income groups and thereby to minimize the public expenditure thereon
- interest rate reforms to encourage greater savings.

These policies were introduced to revitalize the economy. Their aim was economic growth and employment generation largely through private sector participation. It is still too early to evaluate the long and medium term effects of these policies. However, available data suggests

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1. Ministry of Finance and Planning (1980 p.3).

an increased level of activity in the economy. It recorded a relatively high growth rate of 8.20% in 1978, 6.23% in 1979 and 5.52% in 1980 in real GNP compared to annual average growth rate of 3.05% recorded for the period 1970-77. Rate of unemployment also dropped from 24.0% in 1973 to 15.3% in 1978. However, income distribution has worsened in 1978; the income share of the poor has declined; Gini ratio has increased from 0.41 in 1973 to 0.49 in 1978.[1] Even the relatively higher growth rates recorded in 1978, 1979 and 1980 may only reflect immediate reactions to liberalization of the highly controlled economy and therefore one may suspect how well this growth has been founded in the economy. For example, it is worth noting the following, extracted from the Public Investment 1980-1984 (Ministry of Finance and Planning (1980 p.6)):

> "Economic growth in 1979 has come mainly from construction, trade and transport: the higher level of activity in these sectors did not stem from increased activity in agriculture and agriculture processing but were largely related to increased imports following liberalization. .... the growth impulses working in the economy were not sufficiently well-founded in domestic agriculture."

This statement is equally valid for the developments in 1980 as well. The importance of it should be evaluated in the light of the

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1. This is according to the preliminary data of the Consumer Finance and Socio-Economic Survey of 1978. See Central Bank of Ceylon (1979a p.7).

fact that agriculture contributes to the one third of the GDP, one half of total employment and more than 60% of the commodity exports.

1.3 Nature and the Scope of the Study.

Since the late 1950's the Sri Lankan authorities have attempted, without any success, to plan the economic development of the country at a national level.[1] A Ten Year Plan[2] was prepared and published in 1959, but was not implemented. Failure to implement the Ten Year Plan resulted in the introduction of the Short-Term Implementation Programme[3] in 1962, covering only a period of two years, 1962/3 to 1963/4. However, targets of this implementation programme were not fully realised. After the implementation programme of 1962, no development plan was introduced at national level until 1971. However, the Ministry of Planning and Economic Affairs was established in 1965 and it presented a number of sectoral programmes of action on an annual basis, mainly for agriculture and public sector industry. Private sector industry was regulated through the allocation of foreign exchange requirements by the Foreign Exchange Budget Committee. In 1971, a Five Year Plan[4] was presented covering the period 1972-76. A keen interest was taken in implementing it, yet in face of the oil price crisis and food shortages, the plan was abandoned and a crash programme was started to grow more food.

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1. For a detail review of planning experience in Sri Lanka see Karunatilake (1971) and Sirisena (1976).
2. National Planning Council (1959).
3. Department of National Planning (1962).
4. Ministry of Planning and Employment (1971).

The planners in Sri Lanka, bascially viewed economic growth along the lines of Harrod-Domar type of growth models. As a result, the planners thought of planning in terms of volume of investment. However, economic development depends not only on the volume of investment, but also on its efficient allocation. This problem of optimal resource allocation has not been accorded sufficient and systematic attention in economy-wide development planning in Sri Lanka. However, in 1970, with the assistance of the UNDP a medium term planning model was constructed based on an input-output table. This was the first time a model was used to obtain consistent estimates. In 1971, an ILO mission[1] developed a Three Sector Model to demonstrate aspects of the trade-off between full employment and income distribution strategies. There has also been an attempt to develop a ten-sector optimization model. The basic structure of this model is presented in Jayawardane (1970) but the results were not published. As far as can be ascertained, this model has never been improved further and has now been abandoned completely. The five year Plan presented in 1971, does not indicate the influence of a formal planning model.

The present economic policy of the country relies heavily on the market forces. It is expected that market forces will generally govern the savings and investment decisions. As stated in the Central Bank of Ceylon (1979b p.283)

"In a market economy where the private sector is bound to play a leading role in the realisation of these objectives,[2] the necessary

1. International Labour Office (1971).
2. Rapid growth, especially in terms of income generation, employment creation and export development.

motivations are provided through appropriate manipulation in the monetary and fiscal policies of the government and therefore the need for sophisticated development plans become less important."

However, a Five Year Public Investment Programme[1] was presented in 1980 for the period 1980-84 and it contains targets for savings, investment and government revenue as well as projections of sectoral outputs. These projections have been prepared basically on an informal and judgmental basis.[2]

Given these targets and projections, we believe that it is a misjudgment to consider 'sophisticated' (whatever it means) development plans as less important. Without using an economy-wide development planning model, it is not possible to test the consistency of the targets and projections specified in the Public Investment Programme. (PIP hereafter.) Government believes that it could provide the necessary motivation for growth, but to which sectors is the government going to provide incentives? Which sectors are to be given relatively more emphasis? To answer these questions, we should study the optimal development path of the economy. It cannot be done systematically without using an optimisation model.

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1. Ministry of Finance and Planning (1980).

2. Hallett, a short term U.N. adviser to the Ministry of Finance and Planning, outlines the present planning practice in Sri Lanka in Hallett (1981). Considering the informal, judgmental and less checkable nature of the projection method followed by Sri Lankan planners he introduces it as 'calculations done on the back of an envelope.'

The present study is an attempt to demonstrate the importance of using a formal planning technique. A multisectoral intertemporal optimization model is presented and employed to examine the consistency and feasibility among targets and projections given in PIP. However, testing the consistency and feasibility of PIP is not the sole purpose of our study. A number of experiments are undertaken in the model to gain more insight into the structure of the economy and to understand the binding constraints for development. In particular, the importance of domestic savings and foreign financial assistance, implications of public overhead investment and distributional implications of development are investigated. The model is specified in such a way as to facilitate these purposes.

The model specified in this study is basically inspired by the Target Model presented in Eckaus and Parikh (1968) and retains most of the important features of that model. However, our model deviates substantially from the model of Eckaus and Parikh especially with respect to the specification of the objective function, savings constraint and the treatment of public overhead investment. These new features are highlighted in the chapter 3 where the model is presented.

Capital formation is an essential resource requirement for economic development and therefore the importance of savings and investment has been well identified. However, in some developing countries an increase in domestic savings may not necessarily lead to a corresponding increase in investment as the domestic savings are not a perfect substitute for imports. These countries can not increase investment without foreign exchange as they depend heavily on imports for their requirements of investment and intermediate goods for development. Therefore, the availability of foreign exchange becomes a limiting factor for development. As we have seen in section 1.1, Sri Lanka has faced the problem of foreign exchange shortages since the late 1950's. Except for the last few years, the level of investment has been low. Despite the measures taken to promote domestic savings, the level of domestic savings has been lower than the level of investment in most of the years. Under these conditions, it is important to understand the role and interaction of domestic savings and availability of foreign exchange. In this respect, experiments are made in the model to examine the following two issues.

(a) Does availability of domestic savings impose a binding constraint on further growth in Sri Lanka? Given a reasonable ratio of savings by rich and poor households, would it be possible to generate sufficient level of savings by following an optimal path of development? To what extent could economic growth be promoted by taking measures to increase the overall savings ratio and how far is that extent of growth limited by the lack of foreign exchange? What are the implications if the overall savings ratio was lower than the existing level?

Even though the overall savings ratios estimated for the past years may seem low, it does not necessarily mean that the economy's savings potentials are also low. Because, according to Two Gap theory[1)], if a

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1. See chapter 6.pp.180-181 for a brief intorudcion to Two Gap theory and possible adjustment mechanism by which two exante gaps, if not equal, are equalised expost.

country's exante Trade Gap is dominating the exante Savings Gap, there is a possibility that the level of realised savings could fall below the exante level. Further, there is some statistical evidence to suggest that an inflow of foreign financial assistance could adversely affect domestic savings.[1)] Therefore some experimental results from the model devised in this study are analysed to identify the dominating gap for Sri Lankan economy, thereby providing some evidence to justify or refute the hypothesis that inflow of foreign financial assistance would adversely affect domestic savings.

(b) Does availability of foreign exchange impose a binding constraint on further growth in Sri Lanka? If it does, how far could economic growth be promoted by increasing the availability of foreign exchange? The availability of foreign exchange could be increased either through increased availability of foreign financial assistance or by an increase in exports. The importance of an increased availability of foreign exchange through these two channels are examined separately and their differences are highlighted. By parametrically varying the amount of foreign financial assistance available, its productivity is also analysed.

The Public Investment Programme presents a target for an ambitious level of investment on economic and social overheads.[2)] Given the limited availability of resources, it is useful to examine the implications of such an investment programme on the developments within the planning period.

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1. For a critical survey, see Bartels (1975).
2. For details see chapter 4 pp.142-143.

We do not question the importance of at least some of the overhead investments. Yet, if these investments impose a heavy burden on the economy and consequently reduce substantially the level of income attainable within the planning period, it might be worth considering the rephasing of the overhead investments. Therefore, the implication of overhead investments are examined parametrically varying the level of public overhead investments.

Economy-wide development planning models of optimisation nature have always been concerned with the optimisation of a single objective such as consumption or income.[1)] However development planning can better be considered as a problem of decision-making with multiple objectives. Even though various objectives of economic development have been well recognised, no attempt has been made to analyse the multiple objective situation formally. Adelman and Sparrow (1966) having experimented with four objectives separately, conclude that optimal economic profiles are fairly sensitive to differences in objectives. However no attempt was made to provide a plausible solution for multi-objective problems or no formal attempt made to provide sufficient information for the decision maker (DM) to make his final judgement. Karl A. Fox (1966), commenting on Adelman and Sparrow's work, suggested choosing a linear combination of objectives. However, how to decide the weight assigned to each objective has not been discussed.

1. "All mathematical planning models simplify the objectives of development inordinately. For lack of data on policy makers' judgements as well as for computation simplicity even the most ambitious do not go beyond a model in which the sole objective is maximisation of discounted present value of aggregate consumption." Dasgupta et al (1972 p.131.)

In this respect, our study represents a major improvement over the existing models. Two alternative approaches are followed to take into account the multiplicity of objectives. First, considering only the two objectives of consumption (or income) and its distribution, a social welfare function is specified and used as the objective function of the optimisation model; and second, recent developments in Multiple Objective Decision (MOD) methods are employed to resolve the problem imposed by the multiplicity of objectives.

The social welfare function specified in this study, not only takes into account the two objectives of consumption (income) and its distribution, but also resolve the problem imposed by the linearity of objective function in the existing models.[1)] It defines social welfare in terms of the weighted sum of the indirect utility functions of an average poor and rich household, with weights proportioned to the number of households in each group. Also the utility functions used are consistent with the linear expenditure systems for the poor and rich households specified and incorporated within the model. Moreover, the use of this social welfare function enables us to examine the distributional implications of development on an optimal path.

The importance of this should be evaluated considering the well-known hypothesis regarding the relationship between growth and income inequality, and the past experience of growth in developing countries, particularly in Sri Lanka. Kuznets (1955) presents the wellknown

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1. See chapter 3 pp.57-58.

hypothesis that as a low income country develops, the extent of income inequality tends to increase at first, then become stable before it begins to decrease, while Paukert (1973) and Ahluwalia (1974) provide some evidence to support this hypothesis. This suggests that, on average, a developing country will tend to follow a general path. However, this does not mean that all the developing countries will necessarily follow this general path. In fact there are developing countries which have managed to improve the relative distribution as well as experiencing economic growth,[1)] and according to Ahluwalia (1974 p.13), there is little firm empirical basis for the view that higher rate of growth inevitably generates greater inequality. Within this argument about growth and income inequality, Sri Lanka has improved the relative distribution of income from 1963 to 1973 with relatively slow rate of economic growths.[2)] However, by 1978, relative income distribution appears to have changed in favour of the rich, with a higher rate of economic growth than in the earlier period. The earlier development in income distribution has been attributed to income transfer policies[3)] and the structure of production[4)] which prevailed in that period, while

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1. See the country studies presented in Chereny et al (1974 pp.253-290).
2. Lee (1977a and 1977b) attempts to argue that there has not been an improvement in the distribution of incomes from 1963 to 1973. However, Karunatilake (1978) and Lakshman (1976) has refuted his argument.
3. "Sri Lanka is perhaps the most notable case of a government that has used a substantial portion of revenue generated largely by taxing primary exports to subsidise the consumption of poor... This policy has led to a considerable improvement in income distribution, literacy and life expectancy but it has been at the cost of a diminishing rate of growth of GNP and growing unemployment". Chenery (1979, p.35.)
4. Jayawardena (1974 pp.274-77) examines the contribution of production policies to improve the relative income distribution from 1963 to 1970.

Dahanayake (1979) has attempted to explain the later development in terms of the Kuznets' hypothesis.

Within this background of argument and historical experience, it is interesting to analyse the distributional implications of economic growth on an optimal path. It would shed light to our understanding of the past developments and would provide some guideline as to how income distribution might be improved without sacrificing economic growth. By varying the weights assigned to utilities of the poor and rich, one experiment is to see whether it is possible to change the income share of poor and rich substantially by means of production planning. The results of these experiments are analysed to see whether there is a trade off between growth and equality, that is whether the income share of poor households declineswith growth on an optimal path. We also examine the effects of income transfer policies on economic growth and income distribution.

The above approach of specifying a social welfare function is not always practical, particularly if there are a number of objectives, because the specification of weights becomes a critical problem. Specification of weights requires value judgements from the political authorities and they may not be in a position to articulate their preference among objectives. Under this circumstance, we believe that it is possible to make a good use of recent developments in Multiple Objective Decision methods.

There has been a substantial development in Multiple Objective Decision Methods recently.[1)] Some applications of these methods have

1. For a detailed survey, see Cohon (1978), Rietveld (1980) and Hwang et al (1979).

been made in public sector decision-making for such areas as water resource planning, transportation planning, manpower planning in some organisations and financial planning of firms. However, in economy-wide development planning only two applications could be found. In these two applications a special branch of multple objective decision method, that is, Goal Programming, has been used for Korea (Yoon and Hwang (to be published))[1] and Thailand (Tantasuth, 1975). Only Tantasuth's work is available for our reference. In that application we believe that the model is not quite complete: inter-industry transactions have not been taken into account. However, one disadvantage of Goal programming is that it requires the DM to specify the minimum level of achievement which he desires for each goal.

Our study demonstrates the applicability of two specific MOD methods in economy-wide development planning: Hierarchical Programming and Interactive Programming. These two methods appear to be especially attractive considering the preference information which is required from the decision maker. The Interactive Programming method requires no information from the decision maker regarding his preference on objectives a priori and requires only local preferences on a given provisional solution, while the Hierarchical Programming method requires the decision maker to rank objectives according to their importance to him. Moreover, both of the methods are attempted to highlight the relative importance of one method over the other. Individual optimization of each of the objectives would indicate the conflicting or complementary nature of the objectives.

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1. This information is given in Hwang et al (1979).

Conflicting objectives would suggest different strategies of development. Given these different strategies, a unified or compromise strategy of development is derived using the MOD methods.

1.4 Organization of the Study.

Different type of economy-wide development planning models are briefly introduced in chapter 2. The main theme of this chapter is to highlight the important features and weakness of each type of planning models and to defend our choice of an optimising economy-wide planning model.

The model is presented in chapter 3. It highlights some undesirable elements of existing optimising models and emphasises the improvements in the specification of the present model. Having presented the required data for the application of the model for Sri Lanka in chapter 4, results of the various experiments undertaken in the model are presented and analysed in chapters 5, 6 and 7.

In chapter 8, multiple objectives of economic development are identified and MOD methods are introduced and reviewed. This chapter concludes by highlighting the importance of Interactive and Hierarchical programming methods, while chapter 9 demonstrates the applicability of these two methods in economy-wide development planning. The complementary and conflicting nature of the objectives and the strategy of development suggested by each of them is generally discussed. Finally, Hierarchical and Interactive programming methods are used to obtain a unified strategy of development. Given the experience gained by applying these two methods, it also evaluates each of the methods to indicate which of them is more useful as a practical planning technique.

Chapter 10 highlights the main conclusions of the study.

CHAPTER 2.

Economy-wide Models of Development Planning.

2.1 Introduction.

This chapter introduces different types of development planning models. The main theme is to emphasise the important features of each type of model and to discuss their potential applications and limitations. This would provide background information in selecting a certain type of model to handle a particular situation faced by the development planner. Development planning models can be categorised, broadly, into the following four types.

1. Aggregate consistency models.
2. Multisectoral consistency models.
3. Computable General Equilibrium models.
4. Multisectoral optimization models.

Each type of model is reviewed in the following section. However, we do not intend to provide a complete survey of planning models. Taylor (1975) provides a comprehensive survey of the model of the first two and last types. Manne (1974) provides a crticial survey of multisectoral models, giving some suggestions on planning of income distribution. Computable general equilibrium models are a later development and are discussed extensively in Adelman and Robinson (1978) and Dervis, de Melo and Robinson (1982). Therefore we introduce each type of model very briefly and discuss their capabilities and limitations in handling planning problems.

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2.2 Aggregate Consistency Models.

Aggregate consistency models make use of the simple relationships between macro-economic aggregates such as Gross National Product, Consumption, Savings and Investment, at least to provide a forecast of GNP over the planning period. Perhaps the most widely used model in this respect is the well known Harrod-Domar model. At least at the beginning of the planning exercise, planners in developing countries used this model to arrive at some consistent forecast. The Harrod-Domar model itself was not presented as a planning model. However, development planners usually use the following relationship which is a slight modification of the basic Harrod-Domar equation, for planning purposes.[1)]

$$n + p = s\alpha - \delta$$

where n = expected rate of growth of labour force

p = rate of growth of productivity

s = average (marginal) savings rate

α = output capital ratio

and δ = rate of depreciation.

Then they attempt to answer the question, whether or not the economy is able to absorb the expected employment growth, given historical data on savings and depreciation rate and output capital ratio. For many developing countries the answer to this question is negative. The whole

1. Taylor (1975).

economic policy problem starts there.

In some countries Harrod-Domar type models were used explicitly as the framework for plan formulation (e.g. by Tinbergen for the first Turkish Plan). In some other countries this type of model is implicit in the plan documents. As it was pointed out by Bhagwati and Chakravarty (1969), the First Indian Five Year Plan has used a variant of Harrod-Domar model. The only difference was the distinction between the average and marginal propensity to save. Making that distinction it was shown that an economy which decides to save more on the margin than on the average can hope to do better and better over time in terms of its rate of growth.

Models of this type are useful in indicating the basic macro-economic relationships that any more complex models would equally have to satisfy. Also they could be used as a simple mechanism for computing the external assistance that may be necessary for supplementing domestic savings to sustain a projected growth rate in income.[1)]

However, such models have some unsatisfactory features:

(i) They concentrate mainly on flow equilibrium and assume that there are no structural difficulties in transforming savings into

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1. In this respect, importance of Two Gap models should be noted. Two Gap models can be considered as a generalisation of Harrod-Domar specification to take into account the foreign trade bottleneck, in addition to the savings constraint. These models can be used to highlight the dual role of net foreign financial inflows in supplementing domestic savings and financing import requirements for development. The first model of this nature was the aggregate consistency model of Chenery and Bruno (1962). A multisectoral version of a such model is presented in Chapter 3, and a brief introduction to behaviour of macro economic aggregates according to Two Gap approach is available in chapter 6.

investment. This in fact ignores the real constraints in the economy.

(ii) By assuming a constant marginal propensity to save for the economy, such models ignore the fundamental choice problem of planning overtime which requires weighting of present versus future gains.[1)]

(iii) Finally such models assume that economic growth depends entirely upon volume of investment and therefore they ignore the importance of efficient allocation of investment.

The importance of investment allocational problem was emphasised by Mahalanobis (1953, 1955) presenting an ingenious way to handle the problem. He presented two models, to rationalize the investment allocation given in the Second Indian Five Year plan. Both of his models emphasise the importance of investing in capital goods industries.

His two sector model is very similar to one developed independently by Feldman in the Soviet Union in the 1920's and later revised by Domar (1957). In this model current investment flow (I_t) is divided into two parts, $\lambda_k I_t$ and $\lambda_c I_t$ where λ_k indicates the proportion of investment going to the capital goods sector and λ_c the corresponding proportion for the consumption sector.[2)] Now it is clear that

$$I_t - I_{t-1} = \lambda_k \beta_k I_{t-1}$$

$$C_t - C_{t-1} = \lambda_c \beta_c I_{t-1} \quad .$$

1. Bhagwati and Chakravarty (1969 p.5).
2. This exposition follows Bhagwati and Chakravarty (1969).

Using these two relationships he derived a complete solution for output as,

$$y_t = Y_0[1+\alpha_0(\frac{\beta_c\lambda_c + \beta_k\lambda_k}{\beta_k\lambda_k})\{(1 + \lambda_k\beta_k)^t - 1\}]$$

where $\alpha_0 = I_0/Y_0$, the initial investment income ratio.

It is clear from this solution that the asymptotic rate of growth of the system is given by $\lambda_k\beta_k$ where λ_k is the critical allocation ratio which indicates the proportion of capital goods output which is devoted to the further production of capital goods. Therefore a higher λ_k would always have a favourable effect on asymptotic growth rate of the system. However if $\beta_c > \beta_k$, then a higher value of λ_k would imply a lower immediate increment in consumption. Therefore there is implicit in the choice of λ_k a choice of alternative time stream of consumption.

He considered the allocation ratio of current investment going into investment goods sector as a policy variable. Then it was shown that a higher λ_k would mean a higher savings rate on the margin and hence a greater rate of growth of output or consumption. However this model seems to have been used merely to provide the rationale for a shift in industrial investment towards building up a capital goods base. The precise choice of the proportion of investment in capital goods sector during the second plan, appears to have been arbitrary; if there were specific economic considerations underlying it, they were not spelt out.

His second model breaks down total investment flow into following four sectors.

1. Capital goods sector.
2. Factory products of consumer goods.
3. Household products of consumer goods including agriculture.
4. Sector producing services.

Then given the total investment, the problem was to allocate the total between the sectors in such a way that specified increase in income (ΔY) and employment (ΔN) were reached. The policy variables were the shares of investment going to each sector, denoted by λ_1, λ_2, λ_3 and λ_4.

Now since there are only two objectives, ΔY and ΔN, the model is determined only if one of the three independent λ's was exogenously determined. Mahalanobis gave a pre-assigned value to the λ for the capital goods sector and solved the system to assign investment among the three remaining sectors. However as Komiya (1959) pointed out, the Mahalanobis' solution was inefficient in that it was situated in the interior of the feasibility locus between incremental income and incremental employment. Therefore greater employment and/or income could have been obtained by merely reallocating the given investment among the three sectors.

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Therefore it is clear that the practical importance of aggregate consistency models is limited as far as comprehensive development planning is concerned. As it was expressed by Bhagwati and Chakravaty (1969 p.8).

"The very limitations of the Mahalanobis two sector and four sector models pointed to the need for a more extensive, multisectoral and multi-period model for efficient resolution of the choice problems facing the Indian economy."

It is clear that this statement is not specific only to the Indian economy. In comprehensive planning, there are two basic questions to be answered: first, the optimal level of investment, and second, its efficient allocation. The first is clearly a choice problem while the second is mainly an allocational problem. To answer these questions in a systematic manner we have to employ a multisectoral intertemporal optimization model. However, before we examine the importance of the models of that nature, it would be quite useful to review the importance and limitations of multisectoral consistency models which provide the basic core for economy-wide optimization models.

2.3 Multisectoral Consistency Models.

Logical consistency is perhaps the most important property of mathematical planning models. This is the principle virtue of multisectoral models.[1)] The models discussed in the above section are used to test the macro economic consistency within a highly aggregative frame-

1. Manne (1974).

work while multisectoral models derive macro consistency within a multisectoral framework and therefore they also test the consistency of alternative resource allocation programmes.

2.3.1 Static open loop models.

Multisectoral models are usually built around the well know Leontief model of input-output. In the static open loop model, consumption and investment are viewed as final demand and current account inter industry transactions as 'intermediate'. Assuming that the intermediate flows are proportional to gross output, Leontief matrix is employed to calculate the interdependence between final demand vector (F), and gross output vector (X). The output requirement may in turn be checked for consistency with the 'primary resources' that are available.

The material balance relations are the basic components in this type of model. Let $A = a_{ij}$ denote a square matrix of current account inter industry inputs required from sector of origin i per unit of output in sector j. Then the material balance relations are written as,

$$X + M'' = AX + F \qquad (1)$$

gross output plus competitive imports.	=	current account interindustry requirements	+	final demand for consumption investment and exports

Planning applications are based on inverting the (I-A) matrix to find gross output requirements for a forecast of final demand and competitive imports.

$$X = (I - A)^{-1}(F - M'') \qquad (2)$$

This also provides the basis for finding out what quantities of primary resources, (K) , like capital, labour and foreign exchange are required by a given vector of final demand, (F). Let the vector $v = (v_j)$ denote the direct resource requirements per unit of gross output in sector j . Then the total resource requirements implied by the final demand vector (F) are

$$K = VX = V(I-A)^{-1}(F-M'') \qquad (3)$$

These relations are quite useful in partially answering a number of questions which arise during planning process.[1)] For example,

(i) Given a forecast of final demand the relation (3) can be used to check whether it is consistent with the quantities available of each primary resource. If it is not consistent then the final demand forecast may be unrealistic and trial and error revisions will be necessary. This type of error correcting process underlies any serious planning effort.

(ii) As a complement to traditional project evaluation method, these relations can be employed to evaluate the various effects of specific investment projects. Expenditure on a specific investment project could be plugged in as components of vector F . Then the sum of primary resource vector K for each resource would give the direct and indirect resource requirements associated with this particular investment project.

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1. Taylor (1975).

Similarly not only the effects on labour, capital and foreign exchange but also the value added multiplier impacts of this specific investment project can be evaluated.

(iii) Output forecast from (1) can be used as a basis for dialogue with sector specialists. For example 4% aggregate consumption growth may give rise to 3% growth in demand for agricultural products, after input-output calculation. If the supply of agricultural products is only likely to grow at 2%, then there is obvious need for plan revision.

(iv) In association with input-output model, there is an implied price theory as well. The relation, $K = V(I-A)^{-1}(F-M'')$ can be written as $K = P(F-M'')$ where $P = V(I-A)^{-1}$. This P can be interpreted as the price vector since it summarises the direct and indirect resource cost per unit of final demand. This type of cost push price forecast can be used as an element in the formulation of monetary policy. In principle, the price forecast could be used, in conjunction with the quantity projections, to obtain some prediction on government revenue, tax receipts etc.

2.3.2 Closing the system for investment.

In the basic input-output model specified above, all the elements of final demand are considered as exogenous and lumped together in the vector F . This model can be extended to 'endogenize' the elements in F and close the model. In developing countries many capital expenditures are under the direct control of government and therefore efficient investment planning can have a significant impact on growth pattern and can lead to efficient employment of all other resources. Therefore first variable to be closed in a planning model is investment. There are various ways in which investment can be endogenized. In this section, we present two examples, one within a static framework and the other within a dynamic framework, from Indian Planning experience.

2.3.2.1 Static version.[1)]

Net investment by sector of origin is often calculated through an accelerator relationship as follows.

$$K(T) - \bar{K}(0) = B[X(T) - \bar{X}(0)] \tag{4}$$

where elements of vector $\bar{K}(0)$ are initial amounts of each type of capital available in the economy, $\bar{X}(0)$ is a vector of initial output levels and B is a matrix of coefficients b_{ij} representing the amount of capital type i required for an additional unit of output in sector j. This specification gives an estimate of the capital accumulation required from the base year (0) to the target year (T).

Consistent production estimates can be derived for given final demand using an Input-Output model. Then using accelerator specification, target year capital stock can be estimated. Now the problem is to derive a theory of investment which relates capital accumulation to the targeted production lebels and thereby closing the model so that final investment demand is consistent with the endogenous programme of capacity expansion. One way in which this could be done is explained using the consistency

1. Clark (1975).

model presented by Manne and Rudra (1965) in the context of Indian Fourth Plan.

In addition to the material balance relations and accelerator relations, Manne and Rudra added the following two relations to the model.

$$J(T) = d[K(T) - \overline{K}(0)] \tag{5}$$

$$\sum_i M_i' + \sum_i M_i'' = \sum_i \overline{E}_i + W \tag{6}$$

Equation (5) relates investment, $J(T)$ to the desired change in capital stock. The stock flow conversion factor, d, is used to calculate the share of gross fixed capital formation, which will occur in the terminal year of the plan as a share of the ten year investment requirements called to achieve final demand targets set for the terminal year.

Equation (6) is used to calculate the balance of payment deficit. Non competitive imports (M') are related to sectoral output levels by fixed coefficients while competitive imports (M'') are treated as target variables to be altered exogenously to maintain a reasonable foreign aid gap, W.

Now by substituting relations 4, 5 and 6 in 1, these equations can be solved to give sectoral output levels in terms of non-investment final demands by inverting the matrix $[I-A-dB]$. That is, a way of 'endogenizing' investment as demand for capital goods, J, in the system can be computed from 5, once the sectoral production levels for the target year are known.

In this model balance of payment gap is not a fixed resource constraint. Competitive imports and other parameters are adjusted during the course of numerical experimentation, so that trade gap would be in a feasible range of what India might expect to secure from foreign loans and grants. Since these are not policy but target variables, these adjustments imply confidence that import licensing, tariff or an active import substitution policy are economically, politically and institutionally feasible, and will induce the desired results.

As it was pointed out by Clark (1975 p.137)

"If more foreign aid were available to India than was predicted by Manne and Rudra's adjustment of W , it would not be absorbed in the 1970-71 (terminal year) resource allocations implied by the model's solution. Thus the planner must use the estimate of W judiciously. There is nothing implied by the solution about feasible or efficient levels of foreign capital inflow. The judgement of feasibility comes from outside the model."

This type of model can be used to analyse alternative growth paths and policy options in the planning process if it is used as a basis for discussion with agents in the economy who can provide the planner with informed judgements about the plausibility of the model solution. As a result of this interaction, the feasibility of the plan is increased because the judgement and knowledge of those with whom the planner confers will become implicit in the later solutions of the model.

The above model is static and therefore does not explain anything of the transition period between base year and the terminal year. In the next sub-section we explain how an intertemporally consistent plan could be obtained and the problems associated with such an approach.

2.3.2.2 Dynamic version.[1]

Intertemporally consistent models apply the same multisectoral demand and supply patterns reflected in the material balance relations and attempt to work through time to test the dynamic consistency. In this respect a modified version of Leontief dynamic model is employed. In addition to material balance relations (with time subscript attached to each variable) a dynamic model contains the following acceleration relationship.[2]

$$J(t) = B[X(t+1) - X(t)] \tag{7}$$

Substituting this relationship in the commodity balance equation, the basic difference equation for the dynamic model is obtained.

$$X(t) = AX(t) + B[X(t+1) - X(t)] + F(t) \tag{8}$$

$$X(0) \text{ given,}$$

where $F(t)$ is a vector of final demand by origin excluding investment and net of competitive imports.

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1. Taylor (1975), Clark (1975).
2. This is the dynamic version of the incremental relationship specified in equation (4).

Now assuming that B could be inverted,[1)] the above difference equation can be written as

$$X(t+1) = [I + B^{-1}(I-A)]X(t) - B^{-1}F(t) \quad t=0,1,2,... \qquad (9)$$

The general solution to this equation for any given time period t takes the form,

$$X(t) = [I+B^{-1}(I-A)]^{t}X(0) + X^{*}(t) \qquad t=1,2,... \qquad (10)$$

where first part of the right hand side reflects the solution to the 'homogenous' equation for a Leontief system, and $X^{*}(t)$ is a particular solution based on final demand.

The behaviour of the solution to this homogenous equation depends on the magnitude of the characteristic values of the matrix $[I + B^{-1}(I-A)]$. One of these corresponds to the balanced growth path of the system, along which elements of vector $X(t)$ stay in fixed proportion to each other and grow at equal, constant rates. Whether or not output level will converge to balanced growth from arbitrary initial conditions depends on other characteristic values; if any correspond to growth rates exceeding that of the balanced growth characteristic value, the system will diverge and finally generate negative output levels in some sectors. Normally unbalanced growth characteristic values predominate, and even when they do not, the rate of balanced growth will often be improbably high. Since

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such growth would dominate the solution (10) of the non-homogeneous equation even when a 'reasonable' growth of exogenous final demand is built into the particular solution $X^*(t)$, forecasting output increases from arbitrary initial conditions on the basis of (9) is not possible.[1)]

Due to this instability property of the Leontief dynamic model, certain modifications have to be made to obtain a dynamically consistent plan. One way to get around this problem is to relax the key Leontief assumption that no excess capacity is permitted in the economy. An application of this nature is the 'almost consistency' model presented by Bergsman and Manne (1966) in the context of Indian Fourth plan. The basic aims of this model were to construct consistent investment profile for the period 1965-75 and to analyse the long run impact on the balance of payments of early import substitution.

In this model non competitive imports (M_i') are related to output levels while competitive imports (M_i'') are considered a residual supply defined as the difference between demand and production and are called "equilibrating" since they represent changes in planned import substitution. Endogenous investment specification is derived from the accelerator relationship described in equation (4). The terminal year accelerator incorporates post-terminal growth rates (r_i) set as target rates of sectoral capacity expansion

$$J_i(T) = \sum_j b_{ij} r_j X_j(T)(1 + r_j)^{\phi_j - 1} \qquad (11)$$

1. Many formal discussions of the instability of the Leontief dynamic model are available - Chakravarty and Eckaus (1964) Chakravarty (1969) and Jorgenson (1961).

where ϕ_j is the average gestation lag for investment in sector j.

In the first round, competitive imports are set equal to zero. Then substitute (11) into (1) and solve for the terminal year production levels.

$$X(T) = [I - A - Br(1+r)^{\phi-1}]^{-1} F(T) \tag{12}$$

These output levels are compared with the exogenous target year values and the differences in production estimates are interpreted as the equilibrating competitive imports. Now the solution strategy involves backward recurrsion from the consistent terminal year targets to the known initial conditions. (The last year of the Indian Third plan 1965-6 was used as the initial year.) Therefore the process began with consistent demand and supply patterns for three points in time,[1] between which they interpolated to obtain estimates of sectoral values of output, input-output coefficients and all exogenous final demands in the interplan years. Sectoral investment was made consistent using the following accelerator specifications

$$J_i(t) = \sum_j b_{ij}[X_j(t+\phi_j) - X_j(t+\phi_j-1)] \quad 0 < t < T \tag{13}$$

Now the resulting total demand and domestic supply are compared for the inter plan years leaving $M_i''(t)$, the equilibrating imports as the residual. However, for non-traded goods residual can not be interpreted as potential imports, therefore Bergsman and Manne suppressed excess

1. The model took as given in 1970-71 and 1975-76 projections of the economy from the static consistency models of Manne and Rudra (1965) and Sirinivasan, Saluja and Sabherwal (1965).

demand for non-traded goods by lowering exogenous sectoral consumption demands included in $F(t)$ and in non-traded service sectors by adjusting $X_i(t)$ sufficiently to make $M_i''(t) = 0$. However even after this type of adjustments, there remained some sectoral inconsistency, specially in rural construction sector during the early years of the Fourth Plan. Therefore the model was presented as an 'almost consistency' model.

Even after all the above adjustments have been made, the planner must still check the consistency of the resources required. Expost evaluation of the balance of payment gap and savings needs varied considerably among solutions of the model depending upon import requirements of alternative dynamic investment programmes computed by the model. All of these facts lead to the conclusion that the dynamic input-output model alone gives inadequate test of economic feasibility of both exogenous targets and endogenous variables. The model is simply a tool used to structure discussion with policy makers which forces assumptions to be made explicit.

2.3.3 Closing the system for consumption.[1)]

In section (3.2) we considered the way in which investment can be endogenized within both static and dynamic framework. In this section we consider how consumption can be endogenized and analyse income determination and distribution. Research in this field was pioneered by Pyatt and associates (1973). Their work basically depends upon compilation of Social Account Matrix (SAM) in which input-output

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transaction matrix appears as a sub matrix. Based on SAM they build up models to analyse income determination, Keynesion type multiplier effects and income distribution. Within these models two way linkages whereby (i) income distribution affects final demand and hence the structure of production and (ii) structure of production influences factor demands and hence structure of income distribution, have been explicitly incorporated. Studies of this type were undertaken by Pyatt et al (1973, 78) for Iran, Sri Lanka and a few other countries. Sri Lankan case was extensively studied by Pyatt and Round (1979) specially decomposing the multiplier matrix. In this section we do not intend to review this type of modelling work in detail, instead we briefly show how closed loop among production, income and consumption could be specified and thereby generate mutually consistent output and income estimates. In the next chapter where we present our own model for Sri Lanka, such a closed loop is specified within a multisectoral dynamic optimization framework.

In this type of model, consumption is distributed among different types of institutions i.e. rural, estate and urban households etc. Government consumption and investment are considered exogenous. Consumption is specified as a linear function of income earned by each type of household.

$$C_{ik} = \overline{C}_{ik} + y_{ik}Y_k \tag{14}$$

where $\overline{C}_{ik}$ is the intercept term, y_{ik} is the marginal propensity to consume the i^{th} good by each household of type k, out of the income Y_k.

Now substituting (14) in the material balance equation, we get the following relation where two vectors of unknowns are domestic production and personal income.

$$X = AX + yY + F \tag{15}$$

Income received by type k household. Y_k is derived by the following relationship.

$$Y_k = \sum_j v_{k_j} X_j + \sum_k c_{kk} Y_k - \bar{E}_k + T_k \tag{16}$$

where v_{k_j} are fixed proportion value added coefficients for factor earnings paid by sector j to institution k and c_{kk} represent income paid by households to domestic servants, wages and salaries paid by government to civil servant and military personnel. $\bar{E}_k$ represents the net factor payments abroad and T_k government transfers.

Now by lumping all exogenous elements in (16) into vector G, equations (15) and (16) can be simultaneously solved for vectors X and Y.

$$\begin{bmatrix} X \\ \cdots \\ Y \end{bmatrix} = \begin{bmatrix} I - A & \vdots & -y \\ \cdots & \cdots & \cdots \\ -V & \vdots & (1-c) \end{bmatrix}^{-1} \begin{bmatrix} F \\ \cdots \\ G \end{bmatrix} \tag{17}$$

Now the model produces output and income vectors which are mutually consistent since they are computed simultaneously in a fully determined system.

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where v_{k_j} are fixed proportion value added coefficients for factor earnings paid by sector j to institution k and c_{kk} represent income paid by households to domestic servants, wages and salaries paid by government to civil servant and military personnel. $\bar{E}_k$ represents the net factor payments abroad and T_k government transfers.

Now by lumping all exogenous elements in (16) into vector G, equations (15) and (16) can be simultaneously solved for vectors X and Y.

$$\begin{bmatrix} X \\ \cdots \\ Y \end{bmatrix} = \begin{bmatrix} I - A & \vdots & -y \\ \cdots & \cdots & \cdots \\ -V & \vdots & (1-c) \end{bmatrix}^{-1} \begin{bmatrix} F \\ \cdots \\ G \end{bmatrix} \tag{17}$$

Now the model produces output and income vectors which are mutually consistent since they are computed simultaneously in a fully determined system.

Other variables are calculated after the matrix inversion of (17) has been completed. One difference between this type of model and the other models we discussed earlier, is its treatment of imports. In this model commodity balance equation contains only domestic products. In effect, this amounts to considering all imports as non-competitive, since it usually specifies imports as

$$M = \sum_{i} m_j^a X_i + \sum_{k} m_k^c Y_k + \bar{M}^b \tag{18}$$

where m_j^a represents a proportion of intermediate imports coefficient for sector j, m_k^c is a coefficient for consumption goods imports by institution k and $\bar{M}^b$ is the exogenous value of capital goods imported by both private sector and government.

This methodology can be employed to estimate the effects of a hypothetical income redistribution on the factors limiting growth, domestic savings, investment requirements and foreign exchange. Once these are determined, the effects on total output can also be estimated.

2.4 Computable General Equilibrium (CGE) models.

The most recent development in multisectoral consistency models is the introduction of CGE models. Compared to the other type of models, the most distinguished feature of CGE models is that they directly solve for prices. Therefore they are introduced as price endogenous models. These models operate by simulating the operation of factor and product market with profit maximizing firms and utility maximizing households.

CGE models are developed mainly as a laboratory for policy experiments. The main distinguishing features of this type of modelsare:

1. They solve for prices endogenously in both factor and product markets.
2. The solution of such a model is based on achieving a measure of consistency among the results of optimizing behaviour by a large number of individual firms and households.
3. Such a model can incorporate income distribution monetary phenomena, inflation and foreign trade.
4. Such models are dynamic with imperfect intertemporal consistency.
5. They allow for varying principle of market clearing and institutional behaviour.

The overall model consists of a static within period adjustment model linked to a dynamic intertemporal adjustment model. Within period adjustment is constrained by existing capital stock of specific types, by rigidities in wage structure, by immobility of some kind of labour and by government constraints on firm behaviour etc. Between periods, some flexibility for adjustment is introduced by capital accumulation, population growth and migration etc. Accounting consistency is maintained among (1) households, firm, government and trade accounts; (2) national income accounts; (3) input-output accounts and (4) the composition and size of the labour force and households.

Work of this nature was inspired by the pioneering price endogenous planning models of Johanson (1960). Adelman and Robinson (1978) were the first to elaborate this type of model . They developed a highly non-linear complete model for Korea to do laboratory experiments on various income distribution policies. De Melo (1978) developed such a model for Sri Lanka to investigate the effects of a number of agricultural policies on growth rate of GNP and employment, distribution of income and the real income level of the lowest income group. Dervis et al (1982) provides a complete exposition of CGE models and give results of their application of the model to the economy of Turkey. In the following paragraphs, we use Adelman and Robinson (1978) to briefly introduce the basic structure of the model.

The overall model is decomposed into three stages. The Stage I model describes the contracts made between firms and the financial market to spend funds on investment goods. Therefore this models the loanable funds market. Producers form their demand for funds on the basis of expected sales and expected prices of inputs. Then the credit is rationed either by setting an interest rate and allowing the market to clear at that rate or by setting a target rate of expansion of credit and allowing the rate of interest to adjust in order to clear the loanable funds market. The output of Stage I is the allocation of loanable funds among firms and sectors and an overall injection of credit into the economy.

Stage II describes how factor and product markets reach an equilibrium constrained by the investment commitments undertaken in Stage I, by various institutional rigidities imposed by foreign trade, and by the operation of product and labour markets. This is a general equilibrium model in which prices or supplies (or both) are assumed to adjust so as to clear all markets subject to various constraints. This model is sub-divided into a number of parts representing different computational phases in supply, demand, wages, income and price determination. The output of this is 'actual' production, employment, prices, wages and income distribution for the period.

The Stage II reaches its solution by means of a tâtonnement process that simulates market behaviour. However in both Stage I and II no actual transactions take place until the solution of each stage is reached. Therefore investment by firms is determined only at the end of the Stage I; factors are hired, production takes place and income is earned and spent only at the end of Stage II.

Stage III model consists of a set of functions that update the relevant variables and formulate expectations that enter into Stage I model for the next period. This is in fact a collection of sub-models that specifies all the dynamic adjustments and intertemporal linkages for the overall model.

The above is simply the basic structure of CGE models. Basically what differentiates this type of models from other multisectoral models is that they solve endogenously for wages and prices in a multifactor, multiconsumer, multiproduct world in which firm and consumer behaviour is based on the optimization of separate objective functions. These models are useful in experimenting in effects of policies which work mainly by altering the price system.

2.5 Multisectoral Optimization Models.[1]

In section 2.3 we reviewed different kinds of multisectoral consistency models. Certainly models of that type are to be preferred to the aggregate consistency model, considering the amount of information the former generate and their analytical advantages in doing policy experiments. However, there are certain limitations in consistency models, since consistency does not necessarily guarantee economic feasibility. A model may have a number of solutions which are internally consistent, but completely infeasible from macro economic point of view. As we saw in section 2.3, in application of consistency models, feasibility has in fact become a matter of judgement, based on information transmitted from outside the model. On the other hand, feasibility obtained by considering the outside information does not necessarily guarantee an efficient or optimal solution, because consistency models do not have an explicit objective function, and because, in general, there are a large number of solutions which are feasible. To overcome this problem, we should build a consistency model within a linear programming framework. By doing so we can also overcome the instability problem of dynamic Leontief model since linear programming models have the ability to deal systematically with inequality constraints. As we saw earlier, the basic problem with dynamic input-output models arises due to the Leontief key assumption that if a sector has a certain amount of capital installed, all of it should be used to produce output. Also, if a certain rate of imports to domestic product is observed, this ratio becomes a fixed coefficient and there is no endogenous make or buy choice that the model

1. Dervis et al (1982 chapter 3), Taylor (1975).

can simulate. Linear programming (LP) models are atractive because they can allow endogenous choice of capacity utilization and endogenous determination of how much of a good will be imported or exported.

In this section we present the basic features of the LP models. There are a number of versions of LP models (both static and dynamic) applied to various planning problems. For all of these models basic components are an objective function and a set of constraints. Feasible frontier for the economy is defined by the set of constraints which includes material balance relations capital accounting relations and specific resource constraints such as labour, capital, and foreign exchange. Subject to these constraints, an index of social welfare is maximized. The solution gives the optimal values of output, consumption, investment and other endogenous variables, for the entire planning period. In this section, we do not specify the structure of the LP model and the logic behind the solution mechanism, since the next chapter, where our own model is presented, discusses a dynamic programming model in detail. However, for comparative purposes, basic features of the programming approach and the limitations are outlined below.

Optimization planning models provide an efficient and fairly easy means to investigate the frontier of economy's choice set. By careful specification of the constraints, the set of feasible alternatives faced by the economy can be approximated in a fairly realistic manner. The linear programming simplex algorithm is an effective means to get out to the boundaries of this set and parametric programming procedure provides an effective tool to examine the boundaries. Efficient transformation frontier for the economy between the objective function and any specific resource can be examined by parametric variation of the resource available.

LP models have the ability to simulate general equilibrium or competitive resource allocation complete with the prices from the dual solution. This attractive property comes from the duality Theorem and the existence of multipliers that can be interpreted as prices. A 'primal' problem of the form

$$\begin{aligned} &\text{Max} \quad \alpha X \\ &\text{s.t.} \quad MX \leq B \\ &\qquad\quad X \geq 0 \end{aligned}$$

has a dual of the form

$$\begin{aligned} &\text{Min} \quad \lambda B \\ &\text{s.t.} \quad \lambda M \geq \alpha \\ &\qquad\quad \lambda \geq 0 \end{aligned} \qquad 1)$$

where variables λ_i are conceptually very close to the Lagrangean multipliers of classical optimization theory. These multipliers can be interpreted as scarcity indicators or prices and therefore linear programming leads to planning models that not only deal with purely quantitative aspects but also with the 'value' or price implications of alternative solutions. Due to this feature, the LP models can be considered as at least first approximations to computable general

1. Vector α, the matrix M and vector B are the given data and vector X is the vector of decision variables.

equilibrium models of market economy. It can be shown that

$$\frac{\Delta f^*(X)}{\Delta B_i} = \lambda_i^*$$

where ΔB_i represents a small increase in the availability of input i. This ΔB_i leads to a small increase in value of the objective function given by $\Delta f^*(X)$. The ratio of $\Delta f^*(X)$ to ΔB_i is therefore the marginal value productivity of input i and it is equal to the shadow price λ_i of the input in question. Therefore dual multipliers share the marginal productivity property of competitive equilibrium prices and they are signals of relative scarcity.

However, there are certain limitations to the above argument.

As it was repeatedly argued by Dervis et al (1982) equilibrium prices are prices at which the demand and supply decisions of many independent economic actors maximizing their profits and utilities given initial endowments are reconciled. A major requirement is that each actor remains within the budget constraint. In LP models, the total value of inputs will equal the total value of final output, hence duality theorem ensures that the objective function of the dual will equal, at optimum, the objective function of the primal. Therefore overall budget constraint is satisfied. However, nothing guarantees that the budget constraints of the individual actors in the economy are satisfied. Therefore this essential property is absent in standard LP models.

Market clearing prices of general equilibrium theory can accommodate all kind of distortions such as taxes and tariff or monopolitically fixed factor prices. Assume that there are ad volorem taxes in the system. Since the dual price system is not known except as a by-product of the solution of the primal problem, it is not possible to incorporate such taxes into the primal equation system. Therefore it is not possible to analyse the effects of changing prices within LP framework. It is not, for example, possible to explain effects of alternative tariff structures on resources allocation and growth in an economy. It can not be used as a laboratory to test the effects of alternative trade and protection policies that work by altering relative market prices.

However, this does not mean that LP models and their dual prices are not useful. Because, if the analysis of optimal and efficient solution is our only objective, then the fact that shadow prices do not exactly equal market prices is not too disturbing. Shadow prices are, still appropriate indicators of scarcity, given the chosen objective function, technological and resource constraints in the economy, and they yield important insight into the underlying structure of comparative advantage and its evolution over time.

2.6 Concluding Remarks.

Relative importance of multisectoral optimization models over the consistency models was highlighted and the importance of CGE models in simulating the operation of factor and product markets was noted.

The problem to be answered is whether there is any significant advantage in moving from optimization models to CGE models. Clearly the answer depends on the purpose for which the model is supposed to be used. As we have noted, optimization models also contain general equilibrium properties subject to certain limitations. Therefore, significant gains can only be obtained by moving from optimization model to CGE models, if it is required to experiment on the effect of policies which work mainly by altering the price system. On the other hand, if our aim is to study the efficient frontier open to the economy, optimal development path and the specific real constraints for the development, and to examine the way in which these constraints can be alleviated, then a well specified multisectoral optimization model alone would provide a sufficient and efficient tool.

CHAPTER 3.

A Multisectoral Intertemporal Optimization Model for Sri Lanka.

The relative importance of optimization models over consistency models was emphasised in Chapter 2. It was also pointed out that no significant advantage can be obtained by moving from optimization models to computable general equilibrium models, if we do not intend to make laboratory experiments on the effects of policies which work mainly by changing relative price structure. Focussing on the main purpose of our study outlined in the introductory chapter, we now present a multisectoral intertemporal optimization model to study the optimal development path for an economy and to obtain more insight into the structure of the economy. This would enable us to identify the limiting factors for development and to examine the ways in which these constraints could be alleviated.

The model we are about to present is basically inspired by the target model presented by Eckaus and Parikh (1968) in the context of Indian planning. However, we introduce our model as an improvement upon the model of Eckaus and Parikh, since we incorporate substantial changes into their model structure. Therefore, before we present our model, we briefly introduce the model[1)] of Eckaus and Parikh and discuss unsatisfactory features (which we attempt to improve) of available optimization models in general and models of Eckaus and Parikh in particular.

1. In fact, they present four models, i.e. Target, Transit, Guidepath and Guidepost. We refer only to the Target model, but comments are applicable to all four models.

The model of Eckaus and Parikh, maximizes discounted sum of consumption over the five year planning period, subject to consumption growth constraint. Usual material balance relations are incorporated and government consumption and exports are specified exogenously. Investment is related endogenously to increase in capacity (and output) and a fairly complex dynamic structure (three year gestation lags) is introduced. Non-competitive imports are related to sectoral output levels using fixed coefficients and provisions are made to allocate residual available foreign exchange into competitive imports subject to given import ceilings. Terminal stocks are specified exogenously using the official plan targets.

This model is recognised as "The most detailed of all the models so far developed in the context of Indian planning...... within the limitation of a linear model, the structure had sufficient flexibility to handle a number of important planning questions." - Bhagwati and Chakravarty (1969 p.14).

However this does not mean that the model of Eckaus and Parikh is completely satisfactory. There are certain areas where further research is necessary and modifications required. Therefore we now introduce some of these areas where we attempt to make an improvement.

An important element in optimization models is the objective function, since all the results of the model would be conditioned by the choice of the objective function. In economy-wide development planning, this should provide a good approximation to some more detailed social welfare function.

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An important element in optimization models is the objective function, since all the results of the model would be conditioned by the choice of the objective function. In economy-wide development planning, this should provide a good approximation to some more detailed social welfare function.

However, objective functions of the available optimization models are rather poor in this respect; due to the following limitations.

(i) Linearity of the objective function.

(ii) Social Welfare is entirely defined by a single variable such as aggregate consumption or GNP (or in a few cases, aggregate consumption and terminal stocks).

Linearity of the objective function introduces rather unsatisfactory features into the model. Linear maximization problems over time are known to display 'flip-flop' behaviour in consumption and investment levels. This 'flip-flop' behaviour is usually overcome by imposing additional constraints, e.g. consumption growth constraints in the model of Eckaus and Parikh. But this is a rather unsatisfactory solution to the 'flip-flop' problem, because when imposed, this additional constraint becomes more important than the optimization procedure. Usually this constraint takes the form of

$$C(t) \geq (1 + g)C(t-1)$$

where $C(t)$ is aggregate consumption at time t and g is the required minimum rate of growth in consumption. However, in the model solution the inequality would normally be replaced by equality for most values of t.[1] Therefore arbitrary selection of g gets introduced in the model results, in the disguise of optimality.

1. Our preliminary experiments with models of Eckaus and Parikh type confirmed this point. For the five year time period we experimented, inequality held only in the last two years.

On the other hand, a linear objective function assumes constancy in marginal utility of consumption, which is rather unappealing. Therefore a non-linear utility function should be introduced to take into account the diminishing marginal utility of consumption as the consumption rises. There is another non-linearity arising due to the substitution possibility among different types of consumer goods. Therefore introduction of a utility function which exhibits substitution possibilities would be an improvement upon the fixed coefficient approach.

All of the above considerations suggest that we should relax the linearity by introducing a non-linear maximand.

Aggregate consumption maximization approach assumes that social welfare depends entirely upon the aggregate consumption. Therefore, it does not consider the distributional aspects of development. The implicit assumption is that the benefit of growth would subsequently trickle down to the poor segments of the population as well. However, past performance in developing countries has failed, in many cases, to support this assumption. Therefore, we would like to suggest that a positive approach to the distributional problem should be adopted in any serious development planning attempt.

Social welfare does not simply depend on aggregate consumption; its distribution should be taken into account explicitly. According to Manne (1974 p.45)

"Increasingly, it will be important to focus development planning on the problem of choice between alternative income distributions."

In this respect it is worth paying attention to Manne's (1974 p.62) following suggestion.

"Cardinal utility provides a straightforward way to retain the principles of Pareto Optimality and yet to evaluate trade offs between growth and equity. This idea has been introduced into aggregate models of a labour surplus economy by Newbery (1972) and Stern (1972) ..... Thus far, cardinal interpersonal comparisons have not - to my knowledge - been introduced into multisector models. The time seems appropriate for this step."

We attempt to take up this suggestion by specifying a more appropriate objective function which incorporates distributional aspects as well. Our approach takes into consideration the diminishing marginal utility of consumption. A non linear objective function is introduced within linear programming framework using piece-wise linear approximation. A detailed description of our approach is given in the sub-section 3.1.1 on objective function.

The models of Eckaus and Parikh type are classified, in Tendulkar's (1971) terminology, as open loop models, since they consider domestic financing of consumption and investment as exogenous to the system and the optimization process is carried out unconstrained by the availability of domestic resources and subject only to primary resource of foreign exchange. In fact most of the multisectoral models available, for example, Chenery and Kretschmer (1956), Chenery and Uzawa (1958), Bruno (1966), Weisskopf (1971), introduce only the trade constraint in order to bring out the import financing role of foreign capital inflows.

Tendulkar (1971) presented a multisectoral, single period optimization model, that explicitly incorporates two primary bottleneck constraints on economic growth, i.e. domestic savings and foreign exchange, and managed to highlight the interaction between domestic savings and foreign resources, and its effect on economic growth. The models of this type are classified as closed-loop models. Pioneering work in this area was done by Chenery and Bruno (1962) who in an aggregate one sector framework formulated a single period model which introduced both these bottlenecks simultaneously. Tendulkar's model can be considered as a multisectoral generalization of the Chenery-Bruno study. In this sense, our model could be considered as multisectoral intertemporal generalization of the Chenery-Bruno study since we introduce domestic savings constraints within an intertemporal framework. Further, our specification of savings constraint is different from that of Tendulkar's. Instead of relating private savings to wage and non-wage incomes, we specify different propensities to save for 'poor income' and 'rich income' households. Moreover our approach is consistent with the overall private expenditure system introduced within the model and the implicit utility function behind that expenditure system. Incorporation of domestic savings constraint provides us with the facilities to identify the binding constraints on growth and thereby to discuss the relative importance of more domestic savings and more foreign financial assistance.

The models of Eckaus and Parikh have been criticised (Rudra, 1975) for their failure to take account of that kind of fixed capital formation which is in the nature of social and economic overheads, and which is, therefore, not directly related to any capacity creation. Our model takes this into consideration by incorporating exogenously the public investments of a social and economic overhead nature. This inclusion allows us to examine the effects of public investment (social and economic overheads) on other investments and thereby on optimal growth.

In addition to the above improvements, we also introduce an aggregate labour constraint for each period. The assumption of surplus labour may well be suited for a country like Sri Lanka, and therefore aggregate labour supply constraints may become redundant. However, specification of such a constraint would provide an easy means of examining the employment implication of economic development. Severe unemployment problems in a country like Sri Lanka should not be ignored. Taking this into account, in Chapter 9, where we consider the problem of multiplicity of objectives, employment will also be considered as a separate objective and attempts will be made to maximize the employment among other objectives.

Those then are the distinguishing features of our model. In the following section we introduce and discuss the model in detail. Final section discusses the shadow prices which constitute the solution of the dual to the optimization problem.

3.1 The Model.

3.1.1 Objective function.

Ideally the objective function should be a social welfare function.

However, since this is unknown, we should define a good approximation to it. One fairly general formulation of a social welfare function is over the consumption vectors of each of the individuals in the society, i.e.

$$W = f(q^1, q^2, \ldots . q^h : \ldots , q^H) \qquad (1.1)$$

where q^h is the consumption vector of the household 'h'. However this represents no necessary relation to individual preferences. Therefore an obvious restriction of (1.1) is,

$$W = U(u^1, u^2, \ldots , u^h, \ldots u^H) \qquad (1.2)$$

where $u^h = v^h(q^h)$, $h = 1, \ldots H$.

This is the Bergson-Samuelson social welfare function; when (1.1) takes this form, social welfare is said to be individualistic since it is based on individual preferences. Construction of such an individualistic welfare function is difficult - or indeed impossible if we accept Arrow's axioms for social choice. However in Manne's (1975 p.59) words "development planner earns his living by ignoring the axiom of 'non-dictatorship'". In practice, the impossibility problem is solved by the government, the planning authority or any interested individual working with a welfare function which represents that agents view of what social welfare depends on and in what way.

Now the problem is how to make a social welfare function formulated in (1.2) operational. It is obvious from that formulation that two functional relations have to be specified, i.e. $v^h(q^h)$ and $U(\cdot)$. This is the crucial element in specifying a social welfare function which could be applied in practice to solve the planning problem.

Widely applied aggregate consumption maximization approach is an over simplification of (1.2). The implicit assumptions in that approach are that all consumers have the same preference and have equal resource endowments, so that the society could be considered as if it was a single consumer society. In such a society the property of diminishing marginal utility is not that important since the objective is to obtain the largest possible level of consumption. Nor are interpersonal comparison of utilities relevant. It is obvious that these implicit assumptions in aggregate consumption maximization approach are unrealistic. In a society where income distribution is uneven, this would mean that a unit increment in consumption for a poor household has the same social value as such an increment to a rich household. This objection is usually overcome by making another assumption that given the maximum aggregate consumption, government has the ability to make a 'just' distribution. This runs into the problem of possibilities in making lump sum transfers. Normally distributional transfers are huge and possibilities of such transfers are very doubtful. Past experience in developing countries has provided the evidence that rapid growth does not necessarily improve the income distribution. Therefore a positive approach to the distributional problem should be undertaken and the assumption of a single consumer society should be abandoned.

However in a practical application it is not possible to define (1.2) to include each individual explicitly. Therefore some kind of simplification is necessary. One appealing simplification would be to categorise the consumers into different groups and treat each group as a single consumer. Different types of grouping procedures can be suggested. One possibility is to classify consumers into rural, urban and estate groups. This can further be re-classified as rural rich, rural poor, urban rich, urban poor etc. However, while keeping in mind the possibility of such generalization, we work only with two groups of consumers, i.e. rich and poor. Therefore, our approach leads to the assumption of a society with two main consumer groups, but it has the ability of dealing with a large number of consumers as well.

Our approach is inspired by the work of Stern (1972). In an aggregate model of labour surplus economy, he applied the following objective function.[1)]

$$W = \int_0^\infty Lu(C/L) + (N - L)u(\alpha)e^{-wt}\, dt \tag{1.3}$$

where, N is population, C is consumption out of advance sector output, L is employment in the advance sector, α is traditional sector consumption per head and w the discount rate.

Following Stern (1972) but working with finite and discrete time, we can specify our objective function as,

$$W = \sum_{t=1}^{T} [nu(\underline{CR}_t) + (1-n)u(\underline{CP}_t)]/_{(1+w)}{}^{t-1} \tag{1.4}$$

1. Similar function was used by Newbery (1972) and Little and Mirrlees (1969).

where $\underline{CR}$ = per household consumption vector of the rich.

$\underline{CP}$ = per household consumption vector of the poor.

n = proportion of households in the rich income group.

w = social discount rate.

In this manner we have overcome the specification problem of $U(\cdot)$ given $u(\underline{CR}_t)$ and $u(CP_t)$. But specification problem of $u(\underline{CR}_t)$ and $u(CP_t)$ is yet to be resolved.

Before we proceed further, one more point about the aggregate consumption maximization approach is worth mentioning. A common feature of this approach has been to let the maximization procedure determine the aggregate consumption which is distributed among sectors according to the given consumption proportions. This procedure simply ignores the relation between consumption and income. Even in the closed loop model where savings are generated according to the marginal savings ratios, consumption was not explicitly related to income. We consider this as a shortcoming of the available optimization model. Given the income which results from the consumption maximization process, optimal aggregate consumption may not be realised if the community allocates their income according to their propensities to consume sectoral outputs. On the other hand if aggregate consumption is maximized without relating to income, then foreign exchange constraints could never become non-binding as the value of the maximand can be increased by using whatever the foreign exchange is available on import of consumer goods. Such a framework is not so useful in an analysis of relative importance of foreign financial assistance and domestic savings. Therefore we believe that consumption-income relationship should be specified explicitly within the model. Our approach begins with specifying demand relationships for the rich and the poor and $u(\underline{CR})$ and $u(\underline{CP})$ will be specified in a consistent manner with the specified demand system.

We specify consumption-income relationships for both rich and poor as follows.

$$\underline{CR}_t = \alpha_R YR_t \tag{1.5}$$

$$\underline{CP}_t = \alpha_p YP_t \tag{1.6}$$

where α_R and α_p are vectors of average (marginal) propensities to consume sectoral outputs out of per household disposable incomes, YR_t and YP_t for the rich and the poor respectively.

Here we have defined variables in per household terms mainly to avoid scaling problem in the objective function. However, demand relations can well be defined in terms of total consumption of the poor and the rich since α_p and α_R are the same for all within a group. Therefore,

$$T\underline{CR}(t) = \alpha_R TYR(t) \tag{1.5'}$$

$$T\underline{CP}(t) = \alpha_p TYP(t) \tag{1.6'}$$

where $T\underline{CR}$ and $T\underline{CP}$ are consumption vectors for all the rich and the poor households respectively. TYR and TYP are total disposable incomes of the rich and the poor respectively.

This demand system is a simplified version of Extended Linear Expenditure System (ELES)[1]. We have simply ignored the constant term, i.e. 'committed' consumption. This simplification is mainly due to the data limitations. This may not be a serious drawback as we do not intend to make any econometric estimates of the demand system and estimates on α_R and α_P are based on single point observation.

It has been proved (Howe 1975) that the ELES can be obtained from an atemporal maximization of a Stone-Geary utility function[2] by treating savings as a commodity with zero 'committed quantity'. By analogy, our demand system can be considered as a result of maximizing utility functions,

$$u(\underline{CR}) = \sum_i \alpha_{R_i} \ln CR_i \qquad (1.7)$$

and

$$u(\underline{CP}) = \sum_i \alpha_{P_i} \ln CP_i \qquad (1.8)$$

subject to the respective budget constraints.[3]

---

1. Lluch (1973) and Lluch et al (1977).
2. Geary (1950 -51), and Samuelson (1947-48)
3. Budget constraints are,

   $$\Sigma\, q_i CR_i = YR$$

   and $\Sigma\, q_i CP_i = YP$ where q_i is price of commodity i . One of CR_i and CP_i is savings (i.e. future commodities) and corresponding q_i is the price of the future commodities discounted to the present. {c.f. Klein - Rubin (1947-48)}

Therefore this provides a solution to the specification problem of $u(CR)$ and $u(CP)$. However direct application of these utility functions is quite difficult since it increases the number of variables entering into the objective function. Therefore it is more convenient to work with indirect rather than direct utility functions.

Thus by substituting (1.5) and (1.6) respectively in (1.7) and (1.8) we obtain the relevant indirect utility functions, $V(YR)$ and $V(YP)$ as follows.

$$\begin{aligned} V(YR) &= \sum_i \alpha_{R_i} \ln (\alpha_{R_i} YR) \\ &= \ln \prod_i \alpha_{R_i} YR^{\alpha_{R_i}} \\ &= \ln[YR^{\Sigma\alpha_{R_i}} \prod_i \alpha_{R_i}^{\alpha_{R_i}}] \quad . \end{aligned}$$

Now under the assumption that savings also enter the direct utility function and could be considered as another commodity,

$$\sum_i \alpha_{R_i} = 1 \ .$$

Therefore,

$$V(YR) = \ln[YR \ \Pi\alpha_{R_i}^{\alpha_{R_i}}]$$

$$V(YR) = \ln(\phi_R YR) \tag{1.9}$$

where $\phi_R = \prod_i \alpha_{R_i}^{\alpha_{R_i}}$.

Similarly,

$$V(YP) = \ln(\phi_p YP) \tag{1.10}$$

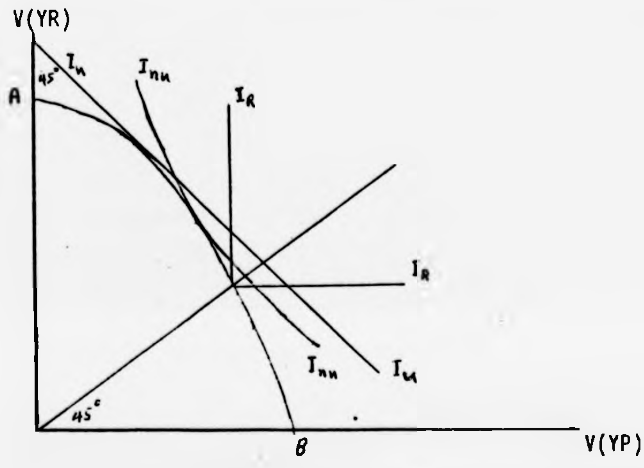
where $\phi_p = \prod_i \alpha p_i^{\alpha p_i}$.

Therefore our social welfare function specified in(1.4) becomes

$$W = \sum_{t=1}^{T} [nV(YR_t) + (1-n)V(YP_t)]/(1+w)^{t-1} \tag{1.11}$$

with $V(YR_t)$ and $V(YP_t)$ as defined in (1.9) and (1.10) with time subscripts.

Social welfare function specified in (1.11) is one of the objective functions we attempt to experiment with. There is another approach which we could employ. This is to define W from $V(YR_t)$ and $V(YP_t)$, making the degree of emphasis on equity a policy variable. This approach is described using the following diagram.[1)]



1. This illustration follows Deaton and Muellbauer (1980 chapter 9).

This diagram illustrates social welfare functions defined on V(YR) and V(YP). Curve AB illustrates the feasible combinations of V(YR) and V(YP).

I_u is an indifferent curve for the utilitarian welfare function, i.e.

$$W = V(YR) + V(YP) .$$

This utilitarian rule is a classical procedure for making social choice. Income is distributed to where it makes the sum of utilities as large as possible. However if we are interested in the distribution of income between the rich and the poor, and wish our social rule to favour equal over unequal distribution, then utilitarianism is not likely to be very useful.[1)] For example, if it is true that policies promoting equality tend to be costly in terms of output, then the utility possibility frontier may well be as illustrated in the diagram. In such a case, utilitarianism will nearly always imply an extremely inegalitarian distribution of welfare.

I_R can be expressed as a Rawlsian social welfare contour. Rawlsian criterion for social choice is a maximin criterion. According to this, if the worst off individual in state S_i is better off than the worst off individual in state S_j, then S_i is socially preferred to S_j. Therefore this is illustrated by right angle indifference curves and as shown in the diagram, a position of complete equality is always optimal provided that utility possibility frontier crosses the 45^o line.

1. This argument depends on the particular cardinality chosen in the utility functions. See footnote 1 on page 71.

I_u and I_R illustrate two extreme cases where former is extremely inegalitarian while the latter favours complete equality. I_{nu} is an intermediate case introduced as a non-utilitarian welfare indifference curve. This intermediate position can be obtained using the following specification.[1)]

$$W = \frac{\{V(YR)\}^{1-\epsilon} + \{V(YP)\}^{1-\epsilon}}{1-\epsilon} \quad \text{for } \epsilon \neq 1 \tag{1.12}$$

$$= \ln V(YR) + \ln V(YP) \quad \text{for } \epsilon = 1$$

This formulation is quite useful since with $\epsilon = 0$ this is utilitarian while as ϵ becomes very large the social welfare indifference curves become more and more like right angles. Intertemporal version of (1.12) would be

$$W = \sum_{t=1}^{T} [\{V(YR_t)\}^{1-\epsilon}/1-\epsilon + \{V(YP_t)\}^{1-\epsilon}/1-\epsilon]/(1+w)^{t-1} \tag{1.13}$$

---

1. It should be noted that all this argument is dependent on the particular cardinality chosen in (1.7) and (1.8). If individual utility functions are

$\frac{V(YR)}{1-\epsilon}^{1-\epsilon}$ and $\frac{V(YP)}{1-\epsilon}^{1-\epsilon}$ then (1.12) itself is Utilitarian.

Therefore it should be emphasised that our specification of W in (1.11) is only one alternative. In addition formulation given in (1.13) can be applied and ϵ could be considered as a policy variable. Sensitivity of results for different values of ϵ could be examined and thereby possible trade-off between growth and equity could be analysed.

It should be noted that our specification of demand system implies unit income elasticity of consumption for all goods. This may not be quite realistic and income elasticities may change as levels of income change. Such properties can be introduced by specifying logarithmic reciprocal functions. However considering the amount of complexities and non-linearities involved, we do not attempt to go to such a length and it needs further research. Our aim is to work within a linear programming framework, and too many non-linearities would remove the main attraction of linear programming.

3.1.2 Income Relationships.

In the above section we defined social welfare in terms of per household income of the rich and the poor. Now we should define the way in which these incomes are formed. Each sector of the economy generates income. The amount of income generated per unit of output x_i, is given by a value added coefficient v_i. This income v_i originated in sector i can be decomposed into V_{R_i}, V_{P_i} and V_{0_i} considering its destination. Here V_{R_i} and V_{P_i} are the amounts of income per x_i received by the rich and the poor households respectively, while V_{0_i}

is the corresponding amount received by the other institutions which are mainly the corporate enterprises. Using these coefficients, income relationships can be expressed as follows:[1)]

$$TYR(t) = (1-t_R)[V_R'X(t) + VG_R(t)] \quad t = 1,\ldots,T \qquad (2.1)$$

$$TYP(t) = (1-t_P)[V_P'X(t) + VG_P(t)] \quad t = 1,\ldots,T \qquad (2.2)$$

$$TYO(t) = (1-t_O)V_O'X(t) \quad t = 1,\ldots,T \qquad (2.3)$$

where V_R', V_P' and V_O' are row vectors of income coefficients for the rich and the poor and the other institutions respectively, and t_R , t_P and t_O are the tax rates applicable for the rich, the poor and the other institutions. Salaries and wages paid by the government ie.value added by the government VG, is specified exogenously. VG_R and VG_P represent the distribution of that income between the rich and the poor households respectively. Per household incomes are obtained by dividing TYR(t) and TYP(t) by the corresponding number of households,

$$YR(t) = TYR(t)/NR \quad t = 1,\ldots.,T \qquad (2.4)$$

$$YP(t) = TYP(t)/NP \quad t = 1,\ldots.,T \qquad (2.5)$$

where NR and NP are the numbers of the rich and the poor households.

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1. For simplicity, all the parameters of the model are specified without a time subscript. However, the possibility of varying them from period to period should be noted.

These income specifications could be used to examine the effects of transferring income from the rich to the poor. This could be done either by including an additional term (government transfers) or by changing t_R and t_P . Negative t_P would mean an income subsidy which is proportional to the level of income earned.

3.1.3 Production Accounting Relationships.

These relationships require that the total demand for each commodity in each period does not exceed the availability of the commodity in that period. Each of the terms in equation (3.1) represents a column vector of n elements where n is the number of sectors.

$$J(t) + H(t) + N(t) + TCR(t) + TCP(t) + G(t) + E(t) \\ \leq M(t) + X(t) \tag{3.1}$$

The left-hand side of this inequality represents the use of output of each sector:

$J(t)$ = intermediate inputs

$H(t)$ = deliveries for inventory accumulation

$N(t)$ = deliveries of investment goods for fixed capital formation (including restoring capital)

$TCR(t)$ = consumption demand by the rich households

$TCP(t)$ = consumption demand by the poor households

$G(t)$ = government consumption

and $E(t)$ = exports.

The right-hand side terms, $M(t)$, imports and $X(t)$ domestic production, are sources of availability of the products.

(a) Intermediate products.

Intermediate requirements for output in each period are determined by an $n \times n$ matrix of input-output coefficients 'a' where a_{ij} is the amount of good i required as an intermediate input to produce one unit of good j

$$J(t) = aX(t) \quad \text{for} \quad t = 1,\ldots,T \tag{3.2}$$

(b) Inventory Accumulation.

Inventory accumulation has to be treated in a less elegant manner due to unavailability of inventory coefficient matrix S where an element S_{ij} is the amount of good i required as inventory in period $t-1$ to produce one unit of good j in period t . Therefore we make use of a diagonal matrix of inventory coefficients $\hat{S}$, where an element s_{jj} is output of sector j held as inventory by sector j itself.

$$H(t) = \hat{s}\{X(t) - X(t-1)\} \quad \text{for} \quad t = 1,\ldots,T \tag{3.3}$$

(c) Private Consumption demand by the rich and the poor household.

These demand systems are already defined in equation (1.5') and (1.6').

(d) Government Consumption.

The amounts required from each sector for government consumption in each period are specified exogenously

$$G(t) = \bar{G}(t) \quad \text{for} \quad t = 1,\ldots,T \tag{3.4}$$

(e) Exports.

Exports are also specified exogenously,

$$E(t) = \bar{E}(t) \quad \text{for} \quad t = 1,\ldots,T \tag{3.5}$$

This in fact is a very rigid treatment. It would have been better if, atleast lower and upper bounds for exports are specified. As the availability of data does not permit us to makeuse of such a specification, the present specification is employed.

3.1.4 Capacity Constraints.

$$bX(t) \leq K(t) \quad \text{for} \quad t = 1,\ldots,T \tag{4.1}$$

$K(t)$ is the vector of fixed capital available at the beginning of the period t and b is the diagonal matrix of sectoral capital output ratios. This constraint ensures that output in each sector, in each period does not exceed the amount producible with the fixed capital which is available at the beginning of that period in that sector. This specification ensures that sectoral capital stocks are non-shiftable in the short-run.

3.1.5 Investment Requirements.

The total capital in each sector is a composite commodity, with a fixed composition. This composition is defined by a proportion matrix P, in which an element P_{ij} represents the good i held as fixed capital by sector j per unit of composite fixed capital K_j.

Sectoral capital stocks can be increased in any period t by the delivery of addition to capacity $Z(t)$. These increments of capacity are formed by deliveries of investment goods from the sectors that produce them. These deliveries are in fixed proportion and with fixed time leads of one and two periods prior to the completion of the addition to capacity. The amount $Z(t)$ that must be furnished by each sector in each period is determined by the two investment lag proportions matrices, P^1 and P^2. The coefficients P^1_{ij} and P^2_{ij} in the matrices indicate the proportions of the total increments to capacity in sector j in period t that must be supplied by sector i in periods $t-1$ and $t-2$. The matrices P^1 and P^2 have a simple relationship to P, P_{ij} being equal to P^1_{ij} and P^2_{ij}. The total amount of deliveries of investment goods in each period is

$$N(t) = P^1 Z(t+1) + P^2 Z(t+2) + \Gamma(t) \quad \text{for } t = 1,\ldots,T \tag{5.1}$$

where $\Gamma(t)$ is exogenously fixed amount of deliveries for social and economic overhead capital. This last kind of investment is not related to capacity creation.

(a) Capital Accounting Relationship.

$$K(t+1) \leq (1-d)K(t) + Z(t+1) \text{ for } t = 1,\ldots, T + 2 \qquad (5.2)$$

d is an exogenously specified rate of capacity depreciation.

This merely states the accounting relationship that $K(t+1)$, the capital available at the beginning of the period $t+1$, cannot be greater than the capacity available from the previous period plus the completed addition to capacity.

3.1.6 Labour Constraints.

It would have been better to have specified labour constraints for each type of labour skills. However, because of the data limitation, we only specify aggregate labour constraint for each period. This constraint may well be non-binding, yet we prefer to incorporate it since it would provide an easy, though rough, way to evaluate the employment implications of the model solutions.

$$\ell' X(t) \leq \bar{L}(t) \quad \text{for } t = 1,\ldots,T \qquad (6.1)$$

where $\ell(t)$ is a vector of elements ℓ_i which are labour requirements per unit of output by sector. Changes in labour productivity can be incorporated by changing ℓ_i from year to year. $\bar{L}(t)$, exogenously specifies the amount of labour available in each period.

3.1.7 Balance of Payments Constraints.

Total amount of imports $\sum_{i=1}^{n} M_i(t)$ in each period cannot exceed the total amount of foreign exchange available, i.e. exports $\sum_{i=1}^{n} E_i(t)$ plus net foreign capital inflows specified exogenously as $\bar{A}(t)$. Thus the balance of payments is

$$i'M(t) \leq \overline{A(t)} + i'E(t) \quad \text{for} \quad t = 1,\ldots,T \tag{7.1}$$

where i' is a unit row vector.

3.1.8 Composition of Imports.

Two types of imports are identified and treated separately, i.e. competitive and non-competitive imports. Some imports are non-competitive in the sense that these are goods for intermediate as well as final uses for which no domestic capacity exists and for which no substitution by domestic output is possible, whatever the relative price of imports and domestic outputs. Competitive imports are goods for which domestic capacity can be created. These are therefore allocated among consuming sectors, depending on the relative cost of imports and domestic production. Total imports in each sector are the sum of the two types

$$M(t) = M'(t) + M''(t) \quad \text{for} \quad t = 1,\ldots,T \tag{8.1}$$

where $M'(t)$ is the vector of non-competitive imports and $M''(t)$ is the vector of competitive imports.

(a) Non-Competitive Imports.

Non-competitive imports are related to sectoral output levels by fixed coefficients

$$M'(t) = mX(t) \quad \text{for} \quad t = 1,\ldots,T \tag{8.2}$$

m is the diagonal matrix of fixed non-competitive import coefficients required by the vector of domestic outputs.

Non-competitive imports are essential and must be made available if there is to be any domestic production. Hence, foreign exchange available to purchase non-competitive imports can set a limit to domestic production. However, non-competitive import coefficients can be changed period by period to take into account planned programmes of import substitution.

(b) Competitive Imports.

Competitive imports make use of whatever foreign exchange is left after non-competitive imports are satisfied. The maximum use of foreign exchange for competitive imports can be stipulated for each sector as in equation (8.3).

$$M''(t) \leq mc\,[A(t) + i'E(t) - i'M'(t)] \quad \text{for } t = 1,\ldots,T \tag{8.3}$$

where vector of coefficient mc is exogenously prescribed so that $\Sigma\, mc_i > 1$. This formulation provides some scope for choice among sectors in the allocation of foreign exchange to competitive imports, but recognising limitations on such choice. However this constraint can be nullified by setting all the mc_i equal to unity so that the model has complete freedom to allocate foreign exchange for competitive imports.

3.1.9 Savings Constraints.

These constraints state that in each period, total investment (including investment in inventories) cannot exceed the total domestic savings plus net foreign capital inflows available.

$$i'N(t)+i'H(t) \leq \alpha_{SR}TYR(t) + \alpha_{SP}TYP(t) + TYO(t) + TYG(t)$$

$$- \{\overline{G}(t) + \overline{VG}_R(t) + \overline{VG}_P(t)\} + \overline{A(t)} \quad t = 1,\ldots,T \qquad (9.1)$$

The first two terms on the right hand side specify, for each period, private savings by the rich and the poor households where α_{SR} and α_{SP} are the respective average (marginal) propensities to save out of disposable incomes.

After tax income of the other institution, $TYO(t)$, represents their retained profit which forms a portion of overall savings.

Government savings are given by,

$$TYG(t) - \{\overline{G}(t)+\overline{V}G_R(t)+\overline{V}G_P(t)\}$$

where the first term indicates its revenue and the rest its current expenditure which are specified exogenously. Government revenue is endogenously generated according to the following relationship,

$$TYG(t) = t_R[V_R'X(t)+\overline{VG}_R(t)]+ t_P[V_P'X(t)+\overline{VG}_P(t)] +$$

$$+ t_0V_0'X(t) + t_X'X(t) + t_e'\overline{E}(t) \quad t = 1,\ldots,T \qquad (9.2)$$

The first three terms on the right specify the revenue received by taxing the incomes of the rich and the poor households and the other institutions. The fourth term specifies the revenue from taxing the output of each sector where t_X' is a row vector of tax rates applicable to each sector. Tax revenue from exports are given by the final item where t_e' is a row vector of tax rates on exports.

For convenience, total investment is expressed at producer values and therefore tax on investment is not included in government revenue.

An important feature of the present specification is that it facilitates the specification of different savings ratios for the rich and the poor and it endogenises government revenue and hence its savings.

3.1.10 Initial Capital Stock and Capital-in-Process.

The capital stock available at the beginning of the first year of the plan is greater than that which produced the output of the pre-plan period (i.e. $\overline{X}(0)$), since additional investment will mature and become available by the end of the pre-plan period, i.e. by the beginning of the first plan period. This capital stock is the initial capacity of the plan. In addition, investment undertaken to mature by the end of the first period must also be specified. Alternatively, maximum gross increments in capacity deliverable by the end of the first period can be specified since they are linked to the pre-plan investment. These initial conditions should be based on empirical information available before the plan begins. However, practically no information has been available on the amounts of uncompleted capital work in process at the beginning of the plan period. Therefore initial conditions are estimated by assuming that in the pre-plan period, for each sector, a growth rate, e_{oi} , has been projected for the creation of capital. Therefore the initial conditions are

$$K(1) = b\ (I+e_0)\overline{X}(0) \tag{10.1}$$

$$Z(2) \leq b\ (e_0+d)(I+e_0)\overline{X}(0) \tag{10.2}$$ [1]

where e_0 is a diagonal matrix of sectoral growth rates, e_{oi} .

3.1.11 <u>Terminal Requirements</u>.

Current economic policy decisions should reflect the reality of an unbroken chain of economic relationships leading from the past

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1. This follows from the capital accounting relationship, $K(2) = (1-d)K(1) + Z(2)$ and expressing $K(1)$ and $K(2)$ in terms of $\overline{X(0)}$ which has been projected to grow at an annual rate of e_{oi}.

into the future. In our model, the stock of capital and capital work in process are the only link in that chain. It is therefore the function of the terminal requirements, formulated as constraints, to reflect the goals of the post-plan future in to the plan period.

$$K(T+1) \geq \bar{K}(T+1) \qquad (11.1)$$

$$K(T+2) \geq \bar{K}(T+2) \qquad (11.2)$$

These terminal stocks, $\bar{K}(T+1)$ and $\bar{K}(T+2)$ can be specified in different ways. Our specification outlined below, follows the target model of Eckaus and Parikh (1968).

The levels of terminal stocks are determined independently and specified as constraints which the model solution must satisfy. It examines the allocational implication of the targets for the plan period. The required minimum capital-in-process at the end of period T is determined by $K(T+2)$ due to the assumed lag of up to two periods between investment and maturity of capital. Alternatively the levels of terminal stocks may be defined in terms of $\bar{X}(T)$, the levels of outputs for the terminal year that are set as targets. It is assumed that each sector grows post-terminally at the annual sectoral growth rate, $e_{\tau i}$ which is implied between $\bar{X}(T)$ and $\bar{X}(0)$. Then using the diagonal matrix b of capital output ratios, terminal conditions are specified as the following constraints.

$$K(T+1) \geq b\ (I+e_{\tau})\bar{X}(T) \qquad (11.1')$$

$$K(T+2) \geq b\ (I+e_{\tau})^{2}\bar{X}(T) \qquad (11.2')$$

This completes the specification of the model which can be used to investigate the implications of a set of specified plan targets. Given the required data, model solution calculates all the direct and indirect requirements implied by the targets, allocates resources to their production and simultaneously distributes the use of resources over time in such a way as to maximise the objective function. If the solution is infeasible, no allocation of resources can be found to meet the targets.

For easy references, Table 3.1 brings together all the symbols used while Table 3.2 outlines all the relationships of the model. Number of constraints can be reduced by substitution and thereby save computer time. The model after substitution is given in Table 3.3 while Table 3.4 presents corresponding tableau.

3.2 Solutions and Shadow Prices.

The model solution, if it exists, allocates resources in such a way as to maximize the value of the objective function. It determines the unknown variables remaining, after all possible substitutions have been made. These are the gross domestic outputs $X(t)$, competitive imports $M''(t)$, capital stocks $K(t)$ and new capital $Z(t)$. With these values it is possible to generate for each period, a detailed list of gross output levels, imports and final demands, inter industry transactions, investment allocations and capital stock uses that will achieve the maximand. These sectoral and temporal details facilitate an overall appraisal of the implications of a solution.

A complete solution includes a set of shadow prices as well. Each of the shadow prices are related to one of the constraints. These are the variables of minimizing valuation problem which is the dual of the primal maximizing problem. As we pointed out in Chapter 2, a shadow price associated with a constraint is the value of change in the objective function when there is a marginal change in the right hand side of the particular constraint and all other constraints are left unchanged.

The meaning of a shadow price can be best appreciated by referring to the corresponding constraint in the dual problem. The constraints of the dual can be read from Table 3.4, reading down the columns.

The prices associated with the production accounting relationships, $P_x(t)$, are the shadow prices of the outputs. From Table 3.4 reading down the column of X(2), for example, we can write the dual relationship as follows.

$$[a+\hat{s}-m-I+\alpha_R(1-t_R)V_R'+\alpha_P(1-t_P)V_P']'P_{x(2)}-\hat{s}P_{x(3)}+bP_{k(2)}+\ell P_{L(2)}$$

$$+mP_{Fx(2)}+mP_{mc(2)}+[s'-t_RV_R'-t_PV_P'-\alpha_{SR}(1-t_R)V_R'-\alpha_{SP}(1-t_P)V_P'-V_0'-t_x']'P_{s(2)}$$

$$-\ SP_{s(3)} \geq dW/dx(2) \quad .$$

This can be written as,

$$[a-m]'P_{x(2)} + \hat{S}[P_{x(2)}-P_{x(3)}] + bP_{k(2)} + \ell P_{L(2)} + m[P_{Fx(2)} + P_{mc(2)}] +$$

$$[(1-t_R)V_R\alpha_R' + (1-t_P)V_P\alpha_P']P_{x(2)} + S[P_{s(2)}-P_{s(3)}] - (t_RV_R+t_pV_p+t_x)P_{s(2)}$$

$$-\ [\alpha_{SR}(1-t_R)V_R + \alpha_{SP}(1-t_P)V_P+V_0]P_{s(2)} - P_{x(2)} \geq dW/dx(2)$$

i.e.

(1)		(2)		(3)	
value of indirect domestic inputs for X(2)	+	value of changes in inventories	+	rental of capital to produce X(2)	+

(4)		(5)		(6)
value of labour to produce X(2)	+	value of imported inputs for X(2)	+	value of the bundle of goods consumed out of the disposable income generated by X(2)

(7)		(8)		(9)
value of the change in inventories at the shadow price of savings	-	marginal contribution of X(2) to tax valued at $P_{s(2)}$	-	marginal contribution of X(2) to private savings valued at $P_{s(2)}$

(10)		(11)
shadow price of X(2)	≥	marginal contribution of X(2) to the social welfare

Items 1 to 5 are the usual cost elements per unit of output and do not need further explanation. In models where there is no savings constraint, and consumption is maximized without relating to output, only elements to appear in the dual constraint are the items 1 to 5 and 10.

Therefore, in these models, we have the usual relation,

$$\begin{matrix}\text{Unit cost of} \\ \text{production of } X(2)\end{matrix} \geq \begin{matrix}\text{shadow price} \\ \text{of } X(2)\end{matrix}$$

and at the optimum for the goods produced exact equality will be held.

In our model items 7 to 9 appear due to our inclusion of savings constraints. Since we have related consumption to disposable incomes and hence to output, items6 and 11 appear in the dual constraint.

Since the amount of savings available in each year, is a scarce resource and inventories make us of some part of this scarce resource, change in inventories has to be valued not only at the shadow price of output, P_X , but also at the shadow price of savings, P_s . This explains the appearance of item 7 in the dual constraints. This could be considered as a tax on output.

Similarly items 8 and 9 can be interpreted as subsidies on output. $(t_R V_R + t_P V_P + t_X)$ is the marginal contribution of $X(2)$ to the government revenue. This directly augments the available amount of savings. Therefore production of $X(2)$ is encouraged, giving a subsidy of $(t_R V_R + t_P V_P + t_X) P_{s(2)}$. Further $X(2)$ contributes to disposable incomes and in its turn augments the availability of savings by $[\alpha_{SR}(1-t_R)V_R + \alpha_{SP}(1-t_P)V_P + V_0]$. Therefore a further subsidy of $[\alpha_{SR}(1-t_R)V_R + \alpha_{SP}(1-t_P)V_P + V_0]P_{s(2)}$ is given to $X(2)$.

Now the items 1 to 5 and 7 to 9 can be lumped together in a vector MC and could be considered as unit cost net of subsidies and inclusive

Therefore, in these models, we have the usual relation,

$$\text{Unit cost of production of } X(2) \geq \text{shadow price of } X(2)$$

and at the optimum for the goods produced exact equality will be held.

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Now the items 1 to 5 and 7 to 9 can be lumped together in a vector MC and could be considered as unit cost net of subsidies and inclusive of producer tax.

$$MC + CP_{X(2)} - P_{X(2)} \geq dW/dx(2)$$

where $C = [(1-t_R)V_R\alpha'_R + (1-t_P)V_P\alpha'_P]$

Now $CP_{X(2)}$ represents the value of the bundle of goods consumed out of the disposable incomes generated by $X(2)$ while $dW/dx(2)$ represents marginal social welfare of that income.

An interpretation of this could be suggested appealing to von Neumann's (1945) model of general equilibrium where goods are produced using all other goods and labour also is a good produced by households using consumption as inputs. In our model V_R and V_P represent salaries, wages and profit and CP_x is the value of goods consumed out of these incomes. Therefore when the labour constraint is not binding CP_X is the cost of labour including entrepreneurs. At the same time that bundle of goods consumed plus savings, i.e. incomes, $(1-t_R)V_R + (1-t_P)V_P$, contribute to the social welfare by the amount $dW/dx(2)$. Therefore it represents a subsidy on $X(2)$.

In the usual models where consumption is not related to incomes, cost of labour becomes zero when labour constraint is not binding. However, even though labour is in excess supply, there is a cost of maintaining labour. Therefore it may be better to consider the value of the bundle of goods consumed as cost of labour at the same time considering the contribution of that consumption plus savings to welfare as a social benefit.

When the labour constraint is binding in addition to the consumption cost of labour, the use of labour represents a further cost due to the scarcity of labour which is given by the shadow price of labour $P_{L(2)}$.

Interpretation of the rest of the shadow prices are quite standard. Therefore we mention them briefly.

The prices associated with the capacity restraints are the shadow rentals of capital in the period of restraints. For example, column K(2) in Table 3.4 gives us,

$$P_{Z(1)} - (1-d)P_{Z(2)} \geq P_{K(2)}$$

i.e.

$$\begin{matrix}\text{value of capital} \\ \text{in period 1}\end{matrix} - \begin{matrix}\text{value of capital} \\ \text{in period 2}\end{matrix} \geq \begin{matrix}\text{shadow rental of} \\ \text{capital in period 2}\end{matrix} .$$

Prices associated with capital accounting relationships are the shadow prices of investments. For example, the dual constraint corresponds to Z(4) from Table 3.4 is as follows.

$$[P^1]'P_{X(3)} + [P^2]'P_{X(2)} + [i'P^1]'P_{S(3)} + [i'P^2]'P_{S(2)}$$
$$\geq P_{Z(3)}$$

i.e.

{cost of inputs} $\geq$ {value of new capital} .

Since investment uses the scarce resource of savings, inputs for investment have to be valued not only at the shadow prices of inputs but also at the shadow price of savings.

Prices associated with balance of payment constraints, $P_{FX(t)}$, can be considered as shadow prices of foreign exchange. However, this does not necessarily mean that it can easily be translated into the shadow price of domestic currency against foreign currency. This is because all of supply and demand forces that affect the foreign exchange rate are not taken into account in the model. Therefore P_{FX} simply indicates the scarcity value of foreign exchange. There are also the shadow prices, P_{mc}, associated with the constraints on the use of foreign exchange for competitive imports. These shadow prices indicate the value, in terms of the maximand, of an additional unit of foreign exchange in the particular sector.

The relationship between the shadow prices associated with the balance of payment constraints, and shadow prices of competitive import ceilings and of output can be obtained from Table 3.4 by reading down the columns $M''(t)$. For example, for $M''(2)$ we have

$$P_{FX(2)} + [mc]^{-1} P_{mc(2)} \geq P_{X(2)}$$

i.e.

$$\begin{array}{c} \text{shadow price associated} \\ \text{with balance of payment} \\ \text{constraints} \end{array} + \begin{array}{c} \text{shadow price associates} \\ \text{with competitive} \\ \text{import ceilings} \end{array} \geq \begin{array}{c} \text{shadow price} \\ \text{of output } X(2) \end{array}$$

TABLE 3.1 Symbols used in the Model.

$A(t)$	net foreign capital inflows in period t
a	matrix of interindustry current flow coefficients
b	diagonal matrix of capital output ratios
CP_t	per household consumption vector of the poor in period t
CR_t	per household consumption vector of the rich in period t
d	rate of capital depreciation
$E(t)$	columns vector of exports by each sector
e_0	diagonal matrix of growth rates used in calculating initial capital and capital in process
e_τ	diagonal matrix of growth rates used in calculating terminal capital requirements
$G(t)$	column vector of deliveries by each sector for government consumption
$H(t)$	column vector of deliveries by each sector for inventory accumulation
$I(t)$	column vector of deliveries by each sector of investment goods for investment in social and economic overhead
i'	unit row vector
$J(t)$	column vector of deliveries of intermediate inputs by each sector

$K(t)$	column vector of fixed capital capacity in each sector
$L(t)$	labour force in period t
ℓ	row vector of labour output ratios
$M(t)$	column vector of total imports
$M'(t)$	column vector of non competitive imports
$M''(t)$	column vector of competitive imports
m	diagonal matrix of import coefficients relating non competitive imports to sectoral output
mc	column vector of coefficients indicating in each sector, maximum use of the foreign exchange available after non competitive import requirements have been satisfied
$N(t)$	column vector of deliveries by each sector of invesment goods for capital formation
n	proportion of the rich households in total households
NR	number of the rich households
NP	number of the poor households
P	capital composition matrix
P^1 , P^2	investment lag proportion matrices for capital
$\hat{S}$	diagonal matrix of inventory coefficients
T	length of the planning periods
t	time, in periods

t'_e row vector of tax rates on exports

t_O rate of tax on income of other institutions

t_P rate of tax on income of the poor households

t_R rate of tax on income of the rich households

t'_x row vector of tax rates on output of each sector

TCP(t) column vector of deliveries by each sector for consumption by the poor households

TCR(t) column vector of deliveries by each sector for consumption by the rich households

TYG(t) government revenue in period t

TYO(t) after tax income of other institutions in period t

TYP(t) disposable income of the poor households in period t

TYR(t) disposable income of the rich households in period t

V'_O row vector of income (value added) per unit of output in each sector, received by the other institutions

V'_P row vector of income (value added) per unit of output in each sector, received by the poor households

V'_R row vector of income (value added) per unit of output in each sector, received by the rich households

$VG_P(t)$ salaries and wages paid by the government to the poor households, in period t

$VG_R(t)$	salaries and wages paid by government to the rich households
W	value of the objective function
w	social discount rate
$X(t)$	column vector of gross domestic outputs
$YP(t)$	per household disposable income of the poor in period t
$YR(t)$	per household disposable income of the rich in period t
$Z(t)$	column vector of additions to fixed capital capacity in period t
α_P	column vector of average (marginal) propensities to consume sectoral output out of disposable income by the poor
α_R	column vector of average (marginal) propensities to consume sectoral output out of disposable income by the rich
α_{SP}	average (marginal) propensity to save out of disposable income by the poor
α_{SR}	average (marginal) propensity to save out of disposable income by the rich
ϕ_P	$\prod_i \alpha_{P_i}^{\alpha_{P_i}}$
ϕ_R	$\prod_i \alpha_{R_i}^{\alpha_{R_i}}$

TABLE 3.2. The Model.

1. Objective Function

Maximize:

$$W = \sum_{t=1}^{T} [n(\ln \phi_R YR(t)) + (1-n)(\ln \phi_P YP(t))]/_{(1+w)}{}^{t-1} \quad (1.1)$$

Subject to:

2. Income Relationships

$$TYR(t) = (1-t_R)[V_R'X(t) + \overline{VG}_R(t)] \qquad t = 1,\ldots,T \quad (2.1)$$

$$TYP(t) = (1-t_P)[V_P'X(t) + \overline{VG}_P(t)] \qquad t = 1,\ldots,T \quad (2.2)$$

$$TYO(t) = (1-t_O)V_O'X(t) \qquad t = 1,\ldots,T \quad (2.3)$$

$$YR(t) = TYR(t)/NR \qquad t = 1,\ldots,T \quad (2.4)$$

$$YP(t) = TYP(t)/NP \qquad t = 1,\ldots,T \quad (2.5)$$

3. Production Accounting Relationships

$$J(t)+H(t)+N(t)+TCR(t)+TCP(t)+G(t)+E(t) \leq M(t)+X(t) \qquad t = 1,\ldots,T \quad (3.1)$$

Intermediate Products

$$J(t) = aX(t) \qquad t = 1,\ldots,T \quad (3.2)$$

Inventory Requirements

(3.3) $H(t) = \hat{S}\{X(t) - X(t-1)\}$ $t = 1,\ldots,T$

Consumption by the Rich

(3.4) $TCR(t) = \alpha_R TYR(t)$ $t = 1,\ldots,T$

Consumption by the Poor

(3.5) $TCP(t) = \alpha_P TYP(t)$ $t = 1,\ldots,T$

Government consumption

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

Exports

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

4. Capacity Constraints

(4.1) $bX(t) \leq K(t)$ $t = 1,\ldots,T$

5. Capital Accounting Relationships

Investment Requirements

(5.1) $N(t) = P^1 Z(t+1) + P^2 Z(t+2) + \overline{I(t)}$ $t = 1,\ldots,T$

Capital Accounting

(5.2) $K(t+1) \leq (1-d)K(t) + Z(t+1)$ $t = 1,\ldots,T+2$

6. Labour Constraints

(6.1) $\ell'X(t) \leq \overline{L}(t)$ $t = 1,\ldots,T$

7. Balance of Payment Constraints

(7.1) $i'M(t) \leq \overline{A}(t) + i'\overline{E(t)}$ $t = 1,\ldots,T$

8. Imports

Import Compositions

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

Noncompetitive Imports

(8.2) $M'(t) = mX(t)$ $t = 1,\ldots,T$

Competitive Import Ceilings

(8.3) $M''(t) \leq mc[\overline{A}(t) + i'E(t) - i'M'(t)]$ $t = 1,\ldots,T$

9. Savings Constraints

(9.1) $$i'N(t)+i'H(t) \le \alpha_{SR}TYR(t)+\alpha_{SP}TYP(t)+TYO(t)+TYG(t)$$

$$- (\overline{G}(t)+\overline{VG}_R(t)+\overline{VG}_P(t)) + A(t) \qquad t = 1,\ldots,T$$

Government Revenue

(9.2) $$TYG(t) = t_R[V_R'X(t)+\overline{VG}_R(t)] + t_P[V_P'X(t)+\overline{VG}_P(t)] + t_0V_0'X(t)$$

$$+ t_x'X(t) + t_e'\overline{E(t)} \qquad t = 1,\ldots,T$$

10. Initial Capital and Capital-in-Process Constraints

(10.0) $$K(1) = b(I+e_0)\overline{X}(0)$$

(10.1) $$Z(2) = b(e_0+d)(I+e_0)\overline{X}(0)$$

11. Terminal Requirements

(11.0) $$K(T+1) \ge b(I+e_\tau)\overline{X}(T)$$

(11.1) $$K(T+2) \ge b(I+e_\tau)^2\overline{X}(T)$$

TABLE 3.3. The Model after substitution.

1. Objective function

Maximize

$$(1.0) \qquad W = \sum_{t=1}^{T} [n \ln \frac{\phi_R}{NR}(1-t_R)\{V_R'X(t) + \overline{VG}_R(t)\} +$$

$$+ (1-n)\ln \frac{\phi_P}{NP}(1-t_P)\{V_P'X(t) + \overline{VG}_P(t)\}]/_{(1+w)}{}^{t-1}$$

Subject to:

2. Distribution Relationships

$$(2.01) \qquad [a + \hat{s} - m - I + \alpha_R(1-t_R)V_R' + \alpha_P(1-t_P)V_P']X(1) +$$

$$+ P^1Z(2) + P^2(3) - M''(1) \leq \hat{s}\overline{X}(0) - \overline{G}(1) - \overline{E}(1)$$

$$(2.02) \qquad [a + \hat{s} - m - I + \alpha_R(1-t_R)V_R' + \alpha_P(1-t_P)V_P']X(t) - \hat{s}X(t-1) +$$

$$+ P^1Z(t+1) + P^2Z(t+2)-M''(t) \leq - G(t)-E(t) \quad \text{for} \quad t = 2,\dots,T$$

3. Capacity Constraints

$$(3.01) \qquad bX(1) \leq b(I+e_0)\overline{X(0)}$$

$$(3.02) \qquad bX(t) - K(t) \leq 0 \qquad \text{for} \quad t = 2,\dots,T$$

4. Capital Accounting Relationships

(4.01) $K(2) - Z(2) \le (1-d)b(I+e_0)\overline{X(0)}$

(4.02) $K(t+1) - Z(t+1) - (1-d)K(t) \le 0$ $\quad t = 2,\dots,T-1$

(4.03) $-Z(T+1) - (1-d)K(T) \le -b(I+e_\tau)\overline{X(T)}$

(4.04) $-Z(T+2) - (1-d)Z(T+1) - (1-d)^2K(T) \le -b(I+e_\tau)^2\overline{X(T)}$

5. Labour Constraints

(5.01) $\ell'X(t) \le \overline{L}(t)$ $\quad$ for $t = 1,\dots,T$

6. Balance of Payment Constraints

(6.01) $i'mX(t) + i'M''(t) \le i'\overline{E(t)} + \overline{A(t)}$ $\quad t = 1,\dots,T$

7. Competitive Import Ceilings

(7.01) $[mc]^{-1}M''(t) + i'mX(t) \le i'\overline{E(t)} + \overline{A(t)}$ $\quad t = 1,\dots,T$

8. Savings Constraints

(8.01)
$$i'P^1Z(2)+i'P^2Z(3)+[s'-\alpha_{SR}(1-t_R)V'_R -$$
$$- \alpha_{SP}(1-t_P)V'_P-V'_0-t_RV'_R-t_PV'_P-t'_X]X(1)$$
$$\leq [(\alpha_{SR}-1)(1-t_R)]\overline{VG}_R(1) + [(\alpha_{SP}-1)(1-t_P)]\overline{VG}_P(1) +$$
$$+ t'_e\overline{E}(1)-\overline{G}(1) + \overline{A}(1)-i'\overline{I}(1)+S'\overline{X}(0)$$

(8.02)
$$i'P^1Z(t+1)+i'P^2Z(t+2) + [s'-\alpha_{SR}(1-t_R)V'_R-\alpha_{SP}(1-t_P)V'_P$$
$$-V'_0-t_RV'_R-t_PV'_P-t'_X]X(t) - s'X(t-1)$$
$$\leq [(\alpha_{SR}-1)(1-t_R)]\overline{VG}_R(t)+[(\alpha_{SP}-1)(1-t_P)]\overline{VG}_P(t) +$$
$$+ t'_e\overline{E}(t)-\overline{G}(t) + \overline{A}(t) - i'\overline{I}(t) \qquad t = 2,\ldots,T$$

9. Initial Capital-in-Process Constraints

(9.01)
$$Z(2) \leq b(e_0+d)(I+e_0)\overline{X(0)}$$

TABLE 3.4. TABLEAU FOR THE MODEL.

		X(1)	M''(1)	X(2)	M''(2)	K(2)	Z(2)	X(3)	M''(3)	K(3)	Z(3)
1. Objective		$dW/dX(1)$		$dW/dX(2)$				$dW/dX(3)$			
2. Distribution Relationships	1.	$[a+\hat{s}-m-I+\alpha_R(1-t_R)V_R' + \alpha_p(1-t_p)V_p']$	$-[1]$				$[P^1]$				$[P^2]$
	2.	$-[\hat{S}]$		$[a+\hat{s}-m-I+\alpha_R(1-t_R)V_R' + \alpha_p(1-t_p)V_p']$	$-[1]$						$[P^1]$
	3.			$-[\hat{S}]$				$[a+\hat{s}-m-I+\alpha_R(1-t_R)V_R' + \alpha_p(1-t_p)V_p']$	$-[1]$		
	4.							$-[\hat{S}]$			
	5.										
3. Capacity Constraints	1.	[b]									
	2.			[b]		-[1]					
	3.							[b]		-[1]	
	4.										
	5.										
4. Capital Accounting Relationships	1.					[1]	-[1]				
	2.					-[1-d]				[1]	-[1]
	3.									-[1-d]	
	4.										
	5.										
	6.										
5. Labour Constraints	1.	$[\ell]'$									
	2.			$[\ell]'$							
	3.							$[\ell]'$			
	4.										
	5.										

TABLE 3.4 TABLEAU FOR THE MODEL (Continued)

		X(4)	M"(4)	K(4)	Z(4)	X(5)	M''(5)	K(5)	Z(5)	Z(6)	Z(7)	$\leq$ $>$	RHS	SP
1. Objective		dw/dx(4)				dw/dx(5)								
2. Distribution Relationships	1.											$\leq$	$\hat{s}\overline{X(0)} - \overline{G(1)} - \overline{E(1)}$	P_x
	2.				$[P^2]$							$\leq$	$-\overline{G(2)} - \overline{E(2)}$	
	3.				$[P^1]$				$[P^2]$			$\leq$	$-\overline{G(3)} - \overline{E(3)}$	
	4.	$[a+\hat{s}-m-I+\alpha_R(1-t_R)V_R' + \alpha_p(1-t_p)V_p']$	$-[1]$						$[P^1]$	$[P^2]$		$\leq$	$-G(4) - E(4)$	
	5.	$-[\hat{S}]$				$[a+\hat{s}-m-I+\alpha_R(1-t_p)V_R + \alpha_p(1-t_p)V_p']$	$-[1]$			$[P^1]$	$[P^2]$	$\leq$	$-\overline{G(5)} - \overline{E(5)}$	
3. Capacity Constraints	1.											$\leq$	$[b](1+e_0)\overline{X(0)}$	P_k
	2.											$\leq$	0	
	3.											$\leq$	0	
	4.	$[b]$		$-[1]$								$\leq$	0	
	5.					$[b]$		$-[1]$				$\leq$	0	
4. Capital Accounting Relationships	1.											$\leq$	$(1-d)[b](1+e_0)\overline{X(0)}$	P_Z
	2.											$\leq$	0	
	3.			$[1]$	$-[1]$							$\leq$	0	
	4.			$-[1-d]$				$[1]$	$-[1]$			$\leq$	0	
	5.							$-[1-d]$		$-[1]$		$\leq$	$-[b](1+e_\tau)\overline{X(5)}$	
	6.							$-[(1-d)^2]$		$-[1-d]$	$+[1]$	$\leq$	$-[b](1+e_\tau)^2\overline{X(5)}$	
5. Labour Constraints	1.											$\leq$	$\overline{L(1)}$	P_L
	2.											$\leq$	$\overline{L(2)}$	
	3.											$\leq$	$\overline{L(3)}$	
	4.	$[\ell]'$										$\leq$	$\overline{L(4)}$	
	5.					$[\ell]'$						$\leq$	$\overline{L(5)}$	

TABLE 3.4. TABLEAU FOR THE MODEL (Continued)

		X(1)	M''(1)	X(2)	M''(2)	K(2)	Z(2)	X(3)	M''(3)	K(3)	Z(3)
6. Balance of Payment constraints	1.	i'm	i'								
	2.			i'm	i'						
	3.							i'm	i'		
	4.										
	5.										
7. Competitive Imports ceilings	1.	i'm	$[mc]^{-1}$								
	2.			i'm	$[mc]^{-1}$						
	3.							i'm	$[mc]^{-1}$		
	4.										
	5.										
8. Savings constraints	1.	$[s'-t_R V'_R - t_P V'_P - \alpha_{SR}(1-t_R)V'_R - \alpha_{SP}(1-t_P)V'_P - V'_0 - t'_x]$					$i'p^1$				$i'p^2$
	2.	$-s'$		$[s'-t_R V'_R - t_P V'_P - \alpha_{SR}(1-t_R)V'_R - \alpha_{SP}(1-t_P)V'_P - V'_0 - t'_x]$							$i'p^1$
	3.			$-s'$				$[s'-t_R V'_R - t_P V'_P - \alpha_{SR}(1-t_R)V'_R - \alpha_{SP}(1-t_P)V'_P - V'_0 - t'_x]$ $-s'$			
	4.										
	5.										
9. Initial Capital in-Process	2.						[1]				

TABLE 3.4. TABLEAU FOR THE MODEL (Continued)

		X(4)	M''(4)	K(4)	Z(4)	X(5)	M''(5)	K(5)	Z(5)	Z(6)	Z(7)	$\lesseqgtr$	RHS	SP
6. Balance of Payment constraints	1.											$\le$	$A(1) + i'E(1)$	P_{FX}
	2.											$\le$	$A(2) + i'E(2)$	
	3.											$\le$	$A(3) + i'E(3)$	
	4.	$i'm$	i'									$\le$	$A(4) + i'E(4)$	
	5.					$i'm$	i'					$\le$	$A(5) + i'E(5)$	
7. Competitive Imports ceilings	1.											$\le$	$A(1) + i'E(1)$	P_{mc}
	2.											$\le$	$A(2) + i'E(2)$	
	3.											$\le$	$A(3) + i'E(3)$	
	4.	$i'm$	$[mc]^{-1}$									$\le$	$A(4) + i'E(4)$	
	5.					$i'm$	$[mc]^{-1}$					$\le$	$A(5) + i'E(5)$	
8. Savings constraints	1.											$\le$	$a_R VG_R(1)+a_P VG_P(1)+t_e'E(1)-G(1)$ $+A(1)-i'I(1)+s'X(0)$	P_S
	2.				$i'p^2$							$\le$	$a_R VG_R(2)+a_P VG_P(2)+t_e'E(2)-G(2)$ $+A(2)-i'I(2)$	
	3.				$i'p^1$				$i'p^2$			$\le$	$a_R VG_R(3)+a_P VG_P(3)+t_e'E(3)-G(3)$ $+A(3)-i'I(3)$	
	4.	$[s'-t_R V_R'-t_P V_P'- {}_{SR}(1-t_R)V_R'$ $- {}_{SP}(1-t_P)V_P'-V_0'-t_x']$							$i'p^1$	$i'p^2$		$\le$	$a_R VG_R(4)+a_P VG_P(4)+t_e'E(4)-G(4)$ $+A(4)-i'I(4)$	
	5.	$-s'$				$[s'-t_R V_R'-t_P V_P'-\alpha_{SR}(1-t_R)V_R'$ $-\alpha_{SP}(1-t_P)V_P'-V_0'-t_x']$				$i'p^1$	$i'p^2$	$\le$	$a_R VG_R(5)+a_P VG_P(5)+t_e'E(5)-G(5)$ $+A(5)-i'I(5)$	
9. Initial Capital-in-Process	2.											$\le$	$[b](e_0+d)(I+e_0)X(0)$	P_{CIP}

$a_R = (\alpha_{SR}-1)(1-t_R) \qquad a_P = (\alpha_{SP}-1)(1-t_P)$

CHAPTER 4.

A Data Base for the Sri Lanka Model

4.1 Data Requirements

In developing countries the use of modern planning techniques has been limited by the lack of necessary data. However an attempt to apply planning techniques is worthwhile even with limited data, since it does at least emphasise the type of data required for sound planning and therefore it could provide a framework to organize data. On the other hand, as it was demonstrated by Pyatt and Roe (1978) (hereafter PR) for Sri Lanka, there exists a wealth of information which could be compiled to fulfil the data requirements of planning models.

Our source of data has been the wealth of information presented in PR and the data published by the Central Bank of Ceylon in its Review of the Economy for 1979 (hereafter CBRE). By now, PR data base is quite old. It is for 1970 at 1970 prices. However, it is not possible for us to update the data base within the limited time available. Data updating itself is a large project which is best undertaken by a group of researchers. Therefore keeping these limitations in mind the PR data have been used extensively. Since the input-output table and most of the other available data have been estimated at 1970 prices, this price level is maintained throughout in all estimations and projections.

As can be seen from the Chapter 3, application of the model specified therein requires data to define the technology and to specify demand. On the production side the following information is needed.

a interindustry flow coefficient matrix

b diagonal matrix of aggregate capital output ratios

P capital proportion matrix

P^1 and P^2 proportion matrices for investment lags

m diagonal matrix of non competitive import coefficients

mc competitive import coefficients for foreign exchange allocation ceilings

ℓ vector of labour output ratios

$L(t)$ labour force available in each year

s diagonal matrix of stock coefficients.

On the income side the following information is required.

V_P, V_R and V_0 vectors of income (value added) coefficients for the poor and the rich households and the other institutions

$VG_P(t)$, $VG_R(t)$ value added by government and its distribution between the poor and the rich for each year

NP, NR number of the poor and the rich households.

t_x, t_I, t_e, t_p, t_R, t_0, tax rates on production, investment exports and institutional incomes.

On the demand side the following have to be estimated for each period.

α_P, α_R vectors of consumption proportion out of disposable incomes for the poor and the rich respectively.

$\bar{E}(t)$ vector of exports

$\bar{G}(t)$ vector of government consumption

$\bar{I}(t)$ vector of public overhead investments

$\bar{A}(t)$ vector of net foreign capital inflows.

In order to specify initial and terminal conditions, the following data are required.

1.(a) $\bar{X}(0)$, vector of domestic output levels in the preplan period.

(b) e_0, diagonal matrix of implicit yearly growth rates projected for the early period of the plan in the preplan years. e_0 along with $\bar{X}(0)$ is used to estimate initial capital stocks and initial capital in process.

2.(a) X(T), vector of domestic output levels for the target year T

(b) e_τ, diagonal matrix of projected post-terminal growth rates X(T) and e_τ are used to specify terminal capital stocks and terminal capital in process.

As one of the purposes of this study is to examine the feasibility of Public Investment Programme for 1980 to 1984 (PIP), the year 1979 is taken as the preplan period with 1984 as the terminal year (T), although, as mentioned earlier, all data are expressed in constant 1970 prices.

4.2 Classification of Sectors

The input-output table presented in PR distinguished 48 production sectors but it was further aggregated for some purposes to 12 sectors. Ideally it is better to have as many sectors as possible. However mainly considering the computational difficulties and limited time available we have to limit the number of sectors to a minimum level. There is a clear trade-off between the number of sectors and the number of time periods considered. In addition, the non-linearity in the objective function makes it more difficult to work with more sectors. Therefore only six sectors are distinguished in our application of the model . This six sector classification is based on the 12 sector classification given in PR. The relationship of 12 sector aggregation to the 48 sector basic data is shown in Table 4.1. Our six sectors and their correspondence to 12 sector classification is as follows.

Six Sectors	12 Sectors
1. Tea and Rubber	1. Tea
	2. Rubber
2. Other agriculture	3. Coconuts
	4. Paddy
	5. Other agriculture
3. Light manufacturing	6. Agri. processing
	8. Traditional industries
4. Modern industry	9. Modern industry (excluding electricity)
5. Mining and Construction	7. Mining
	10. Construction
6. Services	11. Trade and Transport
	12. Services (plus electricity)

TABLE 4.1

CORRESPONDENCE BETWEEN 12 SECTORS AND 48 SECTORS

OF PRODUCTION ACTIVITIES IN PYATT AND ROE STUDY

12 Sectors	48 Sectors	
1. Tea	1. Tea	
2. Rubber	2. Rubber	
3. Coconut	3. Coconut	
4. Paddy	4. Paddy	
5. Other Agriculture	5. Livestock 6. Fishing	7. Logging & Firewood 8. Other Agriculture
6. Agric. Processing	10. Rice Milling 11. Flour Milling 12. Dairy Products 13. Bread 14. Other Bakery Pdct.	16. Dessicated coco. & copra 17. Other Processed Foods 18. Distilling, blending, etc. 27. Coconut Fibre & Yarn
7. Mining	9. Mining	
8. Traditional Industry	19. Tobacco Pdcts. 20. Textiles 21. Wood Prdts. 23. Leather & Prds. 24. Rubber Pdcts.	26. Oils and Fats 30. Ceramics
9. Modern Industry	15. Carbonated Beverage 22. Paper & Paper Pdcts. 25. Chemicals & Pdcts. 28. Petroleum & Coal Pdcts. 32. Basic Metals	33. Light Engineering 34. Transport Equipment 35. Machinery etc. 36. Manufactures n.e.s. 38. Electricity
10. Construction	29. Structural Clay Pdcts. 31. Cement & Pdts.	37. Construction
11. Trade & Transport	39. Road Passenger Trans. 40. Rail Trans. 41. Wholesale Trade	42. Retail Trade 43. Other Transport 44. Communications
12. Services	45. Hotels, Restaurants 46. Prof. Services	47. Dwellings 48. Other Services

As it can be seen, our six sectors are simply a further aggregation of the 12 sectors. The only difference is that we exclude electricity from the modern industry and aggregated it into the service sector. This modification is due to the following reasons.

1. Capital output ratio of electricity (6.95) is much higher than those for the other industries aggregated with the modern industry sector. This ratio is closer to those for industries aggregated in the service sector.
2. Electricity is not a tradable good while all others in the modern industry are tradables.

4.3 Production Data

Production data are a set of ratios for each sector which indicate input requirements per unit of output. In general these ratios can be changed from period to period and from one solution to the other. However in our application we simply assume these ratios to remain unchanged throughout the planning period. The Leontief input output assumption of 'fixed coefficient' of production in volume term has been adopted throughout. The detail descriptions of the data in the original source are not repeated. Only the modifications and adjustments introduced by us are pointed out.

4.3.1 Interindustry Flow Coefficient Matrix

This is estimated by aggregating the 12 sector interindustry transaction matrix contained in Sri Lanka Social Accounts Matrix (SAM) (PR pp. 62-63, Table 3.11). This basic SAM is reproduced here as Table 4.2 for convenience of the reader.

As it can be seen from Table 4.2, in the basic SAM interindustry transactions are defined net of imports and all imports are indicated in a separate row - 'Rest of the World'. However, for our purpose, interindustry transactions have to be defined inclusive of imports. Therefore we redistribute the imports among production sectors using the data available in the 48 sector imports matrix for Sri Lanka (PR-pp. 144-145, Table A17).

Our modified six sector SAM is shown in Table 4.3.[1)] Interindustry flow coefficient matrix is derived from the interindustry transaction matrix contained in this modified SAM and is shown in Table 4.4.

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1. In this SAM the classification of institutions is different from that in the basic SAM. These differences are explained subsequently in pages 125-128.

TABLE 4.2. Sri Lanka Social Accounts Matrix.

Aggregated social-accounts matrix and manpower matrix for Sri Lanka, 1970 (Rs million)

		Factors of production: Urban labour	Rural labour	Estate labour	Housing	Public capital	Private capital	Institutions current accounts: Firms	Households – urban	Households – rural	Households – estate	Government	Combined capital account
Factors of production	Urban labour								38			523	
	Rural labour									56		742	
	Estate labour										6	10	
	Housing												
	Public capital												
	Private capital												
Institutions current accounts	Firms				135	175	1266					294	
	Households – urban	1673			137		662	434				91	
	Households – rural		3184		330		3026	203				151	
	Households – estate			711	31		30	7				6	
	Government							376	368	195	4	104	313
Combined capital account								833	520	808	11	43	
Production activity	Tea								14	56	6	2	−55
	Rubber												25
	Coconut								52	207	30	4	29
	Paddy												49
	Other agriculture								350	988	138	16	
	Agricultural processing								275	1065	138	26	90
	Mining								2	6	1		
	Traditional industry								209	569	79	7	58
	Modern industry								132	335	33	59	17
	Construction											92	1595
	Trade and transport								402	1078	142	89	154
	Services								435	799	60	7	
Rest of world								16	207	741	143	79	364
Total		1673	3184	711	633	175	4985	1869	3004	6903	791	2346	2640

	Production activity: Tea	Rubber	Coconut	Paddy	Other agriculture	Agricultural processing	Mining	Traditional industry	Modern industry	Construction	Trade and transport	Services	Rest of world	Total		
	12	4	11	28	115	32	4	103	84	55	454	210		1673	Urban labour	Factors of production
	49	84	86	719	366	54	16	177	66	107	494	168		3184	Rural labour	
	522	92	22		12	10		1	1	4	17	13		711	Estate labour	
												633		633	Housing	
					−12	16	3	10	67	19		72		175	Public capital	
	2	141	410	231	1095	141	61	145	441	863	1468	100	−113	4985	Private capital	
														1869	Firms	Institutions current accounts
													6	3004	Households – urban	
													6	6902	Households – rural	
													6	791	Households – estate	
	33	4	14	5	19	80	2	263	154	76	130	76	130	2346	Government	
														425	Combined capital account	
												2	839	864	Tea	Production activity
								8					341	374	Rubber	
						247						6	2	577	Coconut	
				70		1012			2					1133	Paddy	
	11	1			95	31	2	62	2	5		39	106	1846	Other agriculture	
					11	34		187	1			40	152	2019	Agricultural processing	
								2	3	74		1	19	108	Mining	
	15				19	19		96	29	102	47	5	92	1346	Traditional industry	
	82	24	9	35	50	24	9	36	329	137	127	31	72	1541	Modern industry	
							1			161	10	47		1906	Construction	
	55	11	9	8	23	116	6	113	138	222	137	62	210	2975	Trade and transport	
	6	2	6	9	1	4			1	6	17	14	280	1647	Services	
	75	12	10	29	53	199	3	143	223	74	74	128		2573	Rest of world	
	864	374	577	1133	1846	2019	108	1346	1541	1906	2975	1647	2573		Total	

Employment category	Tea	Rubber	Coconut	Paddy	Other agriculture	Agricultural processing	Mining	Traditional industry	Modern industry	Construction	Trade and transport	Services	Rest of world	Total	Employment category
Professional	–	–	–	1	1	1	–	1	3	4	4	27		41	Professional
Managerial	1	1	1	–	–	2	1	3	2	1	16	5		33	Managerial
Clerical	5	1	–	–	2	1	–	5	8	3	42	23		90	Clerical
Sales	–	1	–	1	1	5	1	4	3	1	226	22		266	Sales
Agricultural	588	186	45	714	273	34	–	5	3	–	3	–		1851	Agricultural
Miners	–	–	–	–	–	–	12	–	–	–	–	–		12	Miners
Transport	2	–	–	2	–	1	–	1	2	3	104	4		118	Transport
Craft	6	2	1	1	8	32	8	244	57	102	63	33		556	Craft
Service	5	1	3	–	2	4	–	2	2	2	8	114		144	Service
Total employment	607	19	51	719	288	81	21	266	78	116	464	228		3111	Total employment

TABLE 4.3

MODIFIED SOCIAL ACCOUNT MATRIX FOR SRI LANKA (1970)

	ACTIVITIES							INCOMES					REST OF THE WORLD				
	1	2	3	4	5	6	sub total	Poor	Rich	Other	sub total	Gov-mt.	Cap. Acc.	Ex-ports	Im-ports	NET	TOTAL
1. Tea & Rubber			8			2	10	55	21		76	2	-30	1180		1180	1238
2. Other Agri-culture	12	179	1379	4	7	45	1626	1249	656		1905	20	78	108	181	-73	3556
3. Light Manu-facturing	30	39	613	48	106	102	938	2118	1052		3170	35	148	244	1170	-926	3365
4. Modern Industry	168	163	83	516	191	209	1330	294	265		559	47	380	72	961	-889	1427
5. Mining & Construction	3		2	3	255	58	321	6	3		9	92	1595	19	22	-3	2014
6. Services	81	56	249	142	242	387	1157	1584	1389		2973	149	154	490	187	303	4736
Sub Total	294	437	2334	713	801	803	5382	5306	3386		8692	345	2325	2113	2521	-408	16336
Poor Households	758	1978	425	172	505	1389	5227	51	49		100	297				-6	5618
Rich Households	123	936	228	235	369	1966	3857					978				-26	4809
Other Institutions	26	167	36	158	261	367	1015									-79	936
Total Value Added	907	3081	689	565	1135	3722	10099	51	49		100	1275				-111	11363
Government	37	38	342	149	78	211	855	-200	518	82	400	104	314			94	1767
Capital Account								461	856	854	2171	43				425	2639
TOTAL	1238	3556	3365	1427	2014	4736	16336	5618	4809	936	11363	1767	2639	2113	2521	0	

TABLE 4.4.

INTERINDUSTRY FLOW COEFFICIENT MATRIX

	1 Tea & Rubber	2 Other Agri-culture	3 Light Manu-fact.	4 Modern Industry	5 Mining & Construct.	6 Services
1. Tea and Rubber	-	-	0.0024	-	-	0.0004
2. Other Agriculture	0.0097	0.0503	0.4098	0.0028	0.0035	0.0095
3. Ligh Manufacturing	0.0242	0.0110	0.1822	0.0336	0.0526	0.0215
4. Modern Industry	0.1357	0.0458	0.0246	0.3616	0.0948	0.0441
5. Mining & Construction	0.0024	-	0.0006	0.0021	0.1266	0.0123
6. Services	0.0654	0.0158	0.0740	0.0995	0.1202	0.0817
Total	0.2374	0.1229	0.6936	0.4996	0.3977	0.1695

4.3.2 Capital Coefficient Matrix

Aggregate sectoral capital output ratios and their composition were originally estimated by Karunaratne (1973) for 1968, and later updated for 1970.[1)] In this capital coefficient matrix only 5 out of 48 sectors were identified as capital goods producing sectors, i.e

1. Light Engineering
2. Transport Equipment
3. Machinery
4. Construction
5. Wholesale trade.

1. These are given as an Appendix to the 'A Framework for Economic Statistic in Sri Lanka with special reference to employment and Income Distribution for 1970 (unpublished - This in fact is an earlier draft of PR).

In our sectoral classification the first three of the above come under Modern industry and 4 and 5 under Mining & Construction and Services respectively. The 48 sector capital coefficient matrix is aggregated into the six sector classification, weights used are the capital stocks as implied by these coefficients and by the output levels in 1970.

Six sector capital coefficients matrix is given in Table 4.5. Capital proportion matrix P is shown in Table 4.6.

TABLE 4.5

CAPITAL COEFFICIENT MATRIX

	1 Tea & Rubber	2 Other Agric.	3 Light Manu.	4 Modern Ind.	5 Mining & Const.	6 Services
1. Tea and Rubber						
2. Other Agric.						
3. Light Manu.						
4. Modern Industry	0.9462	0.1145	0.5573	1.2974	0.4694	1.6986
5. Mining & Construction	1.2101	0.3297	0.3755	0.6798	0.1988	0.5789
6. Services	0.1265	0.0327	0.0342	0.0272	0.0780	0.0321
Aggregate Capital output Ratio-b	2.2828	0.4769	0.9670	2.0044	0.7462	2.3096

TABLE 4.6

CAPITAL PROPORTION MATRIX P

	1 Tea & Rubber	2 Other Agric.	3 Light Manu.	4 Modern Ind.	5 Mining & Const.	6 Services
1. Tea & Rubber						
2. Other Agric.						
3. Light Manu.						
4. Modern Ind.	0.4145	0.2401	0.5763	0.6473	0.6291	0.7355
5. Mining & Construction	0.5301	0.6913	0.3883	0.3391	0.2664	0.2506
6. Services	0.0554	0.0686	0.0354	0.0136	0.1045	0.0139
TOTAL	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

4.3.3 Lag Proportions Matrices

No empirical information about gestation periods of capital projects is available for Sri Lanka. This kind of information is hard to obtain even for developed countries. Therefore we adopt the procedure used by Eckaus and Parikh to represent the gestation period with a slight modification in the investment lags. This can easily be modified as more information becomes available. We assume that the construction component of investment required to achieve an increment of capacity in period t has to be made in two equal instalments over the two preceding periods t-1 and t-2. For other components of investment, it is assumed thatthe total requirements has to be provided in the period preceding the period in which capacity is to become effective. With these assumptions, the matrices showing proportion of total requirements of each sector in periods t-1 and t-2, for capacity that will mature in period t are estimated and are shown in Table 4.7[1].

TABLE 4.7

LAG PROPORTION MATRICES P^1 AND P^2

P^1	1 Tea & Rubber	2 Other Agric.	3 Light Manu.	4 Modern Ind.	5 Mining & Const.	6 Services
1. Tea & Rubber						
2. Other Agric.						
3. Light Manu.						
4. Modern Ind.	0.4145	0.2401	0.5763	0.6473	0.6291	0.7355
5. Mining & Construction	0.26505	0.34565	0.19415	0.16955	0.1332	0.1253
6. Services	0.0554	0.0686	0.0354	0.0136	0.1045	0.0139
TOTAL	0.73495	0.65435	0.80585	0.83045	0.8668	0.8747
P^2						
1. Tea & Rubber						
2. Other Agric.						
3. Light Manu.						
4. Modern Ind.						
5. Mining & Construction	0.26505	0.34565	0.19415	0.16955	0.1332	0.1253
6. Services						
TOTAL	0.26505	0.34565	0.19415	0.16955	0.1332	0.1253

1. Eckaus and Parikh (1968) introduce gestation lags of up to 3 years. In a preliminary application a three year lag structure was incorporated but was subsequently modified into two year lag structure because the three year lag restricted the feasibility of a solution.

4.3.4 Imports

In order to apply the model, imports have to be classified into competitive and non-competitive groups. By definition, non-competitive imports are the imports for which no domestic capacity exists and for which no substitution by domestic output is possible, whatever the relative prices of imports and domestic output. Strict classification of imports into competitive and non-competitive groups needs an extensive study on the type of goods for which domestic capacity is available and can be created. However, in our classification we simply assume all imported investment and intermediate goods as non-competitive. This assumption is not too unrealistic considering the historically observed relatively very low growth rates (in GDP) in the periods when imports are severely controlled and relatively high growth rates in periods when import controls are relaxed. Among the consumer goods flour, chemical (Pharmerceutical products) and petroleum products are considered as non-competitive. Imports of all services are also treated as non-competitive.

On the above basis non-competitive imports are estimated from the 1970 imports matrix (PR pp. 144-145, Table A.17). Non-competitive imports and non-competitive import coefficients for 1970 are shown in Table 4.8.

CBRE classifies imports into consumer, intermediate and investment goods. Information available in Tables 7.5, 7.6 and 7.11 of CBRE is used to distribute imports of 1979 among our six sectors on a rough basis. These imports are expressed at 1970 prices, deflating current values by respective import price indices for consumer, intermediate and investment goods (CBRE Table 66). In turn 1979 non-competitive imports at 1970 prices are estimated. These non-competitive imports are also shown in Table 4.8 along with non-competitive import coefficients for 1979.

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TABLE 4.8

NON-COMPETITIVE IMPORTS AND NON-COMPETITIVE IMPORT COEFFICIENTS, m, FOR 1970 AND 1979.

	1970			1979 at 1970 prices		
	non-comp. imports	Gross output	m coefficient	non comp. imports	Gross output	m coefficient
1. Tea & Rubber		1238	0.		1189.93	0.
2. Other Agric.	41	3556	0.0115	44	4620.49	0.0095
3. Light Manu.	444	3365	0.1319	402	4021.03	0.1000
4. Modern Industry	931	1427	0.6524	1522	2494.01	0.6103
5. Mining & Const.	22	2014	0.0109	11	3200.57	0.0034
6. Services	187	4736	0.0395	156	7088.87	0.0220
TOTAL	1625	16336	0.0995	2135	22614.90	0.0944

Substantial decreases in the coefficients can be seen from 1970 to 1979. However, in using these coefficients following points should be kept in mind.

(1) Coefficients estimated using non-competitive imports and gross output levels at current prices show substantial increases in the coefficients from 1970 to 1979. This may simply reflect the fact that prices of imports have been rising at higher rates than domestic output.

(2) Our estimates of imports at constant prices may be biased due to possible errors in estimating import price indices.

(3) This may reflect the results of past import substitution programmes. Import substitution has been quite effective, especially in agriculture and agriculture based industries.

In consideration of the above points, both sets of coefficients are used within the context of alternative solutions.

The foreign exchange left after the satisfaction of non-competitive import requirements i.e. the uncommitted foreign exchange, can be used to finance competitive imports. The model was specified in such a way that ceilings can be set on the use of the uncommitted foreign exchange to import competitive goods to supplement domestic output in each sector. These ceilings are in the form of ratios of uncommitted foreign exchange. In our application, these ratios are not specified as to some extent such specification seems to be arbitrary. Therefore, competitive import ceiling constraints are dropped, allowing the optimisation procedure allocate uncommitted foreign exchange on all sectors except mining and construction and services. Since all imports of intermediate inputs and services were considered as non-competitive, competitive imports are not allowed in mining and construction and services. This was done by imposing constraints requiring no competitive imports in these two sectors.

4.3.5 Labour Requirements and Labour Force available

A manpower matrix (1970) for Sri Lanka is available in PR. Information available therein is used to estimate labour output ratios for 1970 and reported in Table 4.9.

TABLE 4.9

EMPLOYMENT AND LABOUR OUTPUT RATIOS ℓ.

IN 1970

		1970	
		Employment ('000)	Labour output ratio ℓ
1.	Tea & Rubber	797.9	0.6445
2.	Other Agriculture	1058.6	0.2977
3.	Light Manufacturing	345.0	0.1025
4.	Modern Industry	64.5	0.0452
5.	Mining & Construction	136.8	0.0679
6.	Services	707.5	0.1494
	TOTAL	3110.3	0.1904

Some estimates of employment in 1979 are available in Ministry of Finance and Planning (1980 p.24), but they are not detailed enough to estimate sectoral labour output ratios. Thus labour output ratios estimated for 1970 are used in our application of the model.

These ratios are inevitably crude. For instance, no adjustments are made to reflect the productivity changes simply because the availability of data does not permit it.

According to Central Bank of Ceylon (1980, p.108), the size of the labour force which stood at 4.5 million during the 1971 census had grown by 27% to an estimated figure of 5.7 million by 1979. This represents 3% annual average growth in the labour force. Assuming this rate to remain unchanged during the planning period, the labour force is projected for each year from 1980 to 1984.

Employment by Government in 1979 was estimated at 0.469 million which represents a 5.3% growth over 1978.[1] Consistant with our assumption of 5.3% growth in value added by Government,[2] employment by government is assumed to grow at the same rate, during the period 1980-1984, thereby assuming no change in real wage rates. Accordingly, employment by government is projected for each year and subtracted from the projected labour force to obtain projected labour force available for employment in the other sectors. These projections are reported in Table 4.10.

TABLE 4.10

PROJECTED LABOUR FORCE 1980-1984

('000)

	1979 (pre plan year)	1980	1981	1982	1983	1984
Labour Force	5700	5871	6047	6229	6415	6608
Employment by the government	469	494	520	548	577	607
Labour Force available for other sectors{$L(t)$}	5231	5377	5527	5681	5838	6001

1. Central Bank of Ceylon (1981 p.16)

2. see page 129 of this chapter.

4.3.6 Stock Coefficients

Practically no estimates of inventory output coefficients are available for Sri Lanka. Therefore we simply relate changes in stocks to changes in output levels, using a diagonal matrix of stock coefficients. These coefficients are specified according to Jayawardane (1970) and are given below.

1. Tea & Rubber	0.005
2. Other Agriculture	0.010
3. Light Manufacturing	0.060
4. Modern Industry	0.020

These coefficients are based on guess work. However, the demand created by stock changes are quite small and therefore any errors due to misspecification of stock coefficients are likely to be minimal.

4.4 Data for Estimation of Incomes

Incomes are generated by production activities and the activities of the government. For our purpose we identify four types of institutions which ultimately receive either these directly, or through income transfers between institutions.

1. Poor households
2. Rich households
3. Government
4. Other institutions (private and public owned corporations).

The demarcation between "poor" and "rich" households is made according to a household income level of approximately Rs6800 per annum. This classification is based on the work of Tyler and Roe (1977). It is inevitably arbitrary, but it is made to capture some notion of inequality and distribution. They have directly routed all receipts and payments of factors of production from source to their ultimate destination and also the profit earned by private firms and transfered to households have been directly incorporated into household accounts. Our classification of institutions presented in Table 4.3 is a direct adaptation of the information available in Table 2 of Tyler and Roe (1977). However, in the intersection of 'government' column and 'incomes' row we present only the distribution of value added by government while Tyler and Roe include government transfers too.

Value added by government is distributed between poor and rich households on the following basis.

Among the government employees, professional, technical and related workers and administrative, executive and managerial workers are considered as rich while all others are poor. Again, this is an arbitrary allocation for reason of expediency. On this assumption Table 4.11 is prepared using the data given in PR - Manpower Matrix (1970).

TABLE 4.11

GOVERNMENT EMPLOYEES ('000)

	Rich	Poor	Total
Urban	41.3	49.3	90.6
Rural	89.5	83.2	172.7
Estate	1.8	0.8	2.6
TOTAL	132.6	133.3	265.9

Tyler and Roe (1977) present the following information on average incomes.

TABLE 4.12

AVERAGE INCOMES (Rs.p.a.)

	Rich	Poor
Urban	15402	4179
Rural	10607	3339
Estate	7310	2895

These employment and average income data are used to estimate hypothetical income from government value added of poor and rich households respectively. Then the actual value added by government is distributed between poor and rich households according to the ratio indicated in the hypothetical incomes.

Now the difference in the figures given in the intersection of 'government' column and 'income' row in our Table 4.3 and Tyler & Roe Table 2 are the transfers from the government. These transfers are incorporated in the 'government' row as negative receipts from the institutions. Therefore intersection of the 'incomes' column and 'government' row shows net contribution of each institution towards government revenue.

Now the information available in Table 4.3 is sufficient to estimate all coefficients required to estimate incomes.

It should be noted that in our model we simply ignore the value added by domestic servants and net factor incomes from abroad. Both the value added by domestic servants and net factor incomes from abroad in 1970 were less than one percent of the GNP and therefore these omissions are not likely to be significant.

4.4.1 Income Coefficients for Poor and Rich Households and for other Institutions

These coefficients are simply the ratios between respective institutional incomes and gross value of output for each sector. Estimated coefficients are given in Table 4.13.

TABLE 4.13

INCOME COEFFICIENTS

	Poor Households V_P	Rich Households V_R	Other Institutions V_0	Total Value Added Ratio V
1. Tea & Rubber	0.6123	0.0993	0.0210	0.7326
2. Other Agriculture	0.5562	0.2632	0.0470	0.8664
3. Light Manufacturing	0.1263	0.0678	0.0107	0.2048
4. Modern Industry	0.1205	0.1647	0.1107	0.3959
5. Mining & Construction	0.2507	0.1832	0.1296	0.5635
6. Services	0.2933	0.4151	0.0775	0.7859

4.4.2 Value Added by Government and its Distribution

Total value added by government is assumed to be a constant proportion of the value added in services. This implies that value added by government grows at the same rate as the total services. Total services has grown by 49.68% from 1970 to 1979 while PIP projects 5.3% average annual growth in services from 1979 to 1984. Using the same ratios value added by government is estimated for each year from 1980 to 1984 taking 1970 value of Rs. 1275 mn. given in PR as the base. Then the total value added figures are distributed between poor and rich households using the ratio estimated for 1970. These estimates are shown in Table 4.14.

TABLE 4.14

VALUE ADDED BY GOVERNMENT AND ITS DISTRIBUTION (at 1970 prices)

(Rs. million)

	1980	1981	1982	1983	1984
1. Poor Households VG_p	468	493	519	546	576
2. Rich Households VG_R	1542	1623	1709	1800	1895
TOTAL	2010	2116	2228	2346	2471

4.4.3 Number of the Poor and Rich Households

In order to express incomes of the poor and rich households in per household terms, numbers of the poor and rich households have to be specified. These numbers for 1970 are given in Tyler and Roe (1977). We updated them for 1979 under the following assumptions.

1. Total number of households are proportional to the total population and therefore, it has grown by the rate of growth of population.
2. Distribution of households between the poor and rich has remained unchanged from 1970 to 1979.

Accordingly, the numbers of poor and rich households in 1979 are estimated and reported below.

Number of the poor households	1972914
Number of the rich households	469562
TOTAL:	2442476

These estimates are used to express incomes in per household terms. Changes in the number of households from 1979 through the planning period are not considered, as we have not incorporated the dynamics of population growth within the model. Incomes are expressed in per household term merely to avoid the scaling problem in the objective function.

Specification of the objective function requires the proportion of the rich households, n. According to the above estimates this proportion is 0.8077.

4.4.4 Government Revenue

As it can be seen from Table 4.3 government revenue consists of tax on production, investment, exports and net tax (all taxes on institutions net of transfer from the government) on institutions. Production taxes are expressed as proportions of gross output levels for each sector, while tax on investment is expressed as a proportion of total investment. Net taxes on institutions are expressed as proportion of institutional incomes. These proportions are directly computed from Table 4.3 and are shown in Table 4.15.

TABLE 4.15

TAX RATES

1. Tax on Production	
1. Tea and Rubber	0.0299
2. Other Agriculture	0.0107
3. Light Manufacturing	0.1016
4. Modern Industry	0.1044
5. Mining & Construction	0.0387
6. Services	0.0445
2. Tax on Investment	0.1350
3. Net tax on Institutional Incomes	
(1) Poor Households	-0.0359
(2) Rich Households	0.1083
(3) Other Institutions	0.0876

Tax rates on exports are not shown in Table 4.15. These taxes are calculated on a sectoral basis and are shown in Table 4.23.

Furthermore, the application of the model does not require knowledge of a tax rate on investment. However, it is reported here because it is used in compiling macro economic aggregates of the model solutions in Chapter 6. For this computation, all taxes on production, exports and investment are considered as indirect taxes. Net indirect tax on consumption is estimated at a level of 1.3691% using the data given in PR.[1)]

4.5 Demand Data

4.5.1 Consumption by Poor and Rich Households

The model require specification of consumption proportions out of disposable incomes for poor and rich. These proportions are directly estimated from the consumption patterns exhibited in Table 4.3 and are shown in Table 4.16.

---

1. Table A.16 pp. 142,143.

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---

1. Table A.16 pp. 142,143.

TABLE 4.16

CONSUMPTION PROPORTIONS OUT OF

DISPOSABLE INCOMES

	Poor Households	Rich Households
1. Tea & Rubber	0.0095	0.0050
2. Other Agriculture	0.2166	0.1546
3. Light Manufacturing	0.3673	0.2480
4. Modern Industry	0.0510	0.0625
5. Mining & Construction	0.0010	0.0007
6. Services	0.2747	0.3274
TOTAL	0.9201	0.7982
Savings	0.0799	0.2018

It should be noted that 'other institutions', which are primarily corporate enterprises, do not consume. Out of total income a proportion of 0.0876 is paid to the government and the rest (0.9124) is saved (i.e. retained profit).

4.5.2 Government Consumption

Government consumption is assumed to be proportional to the value added by the government. This proportion was approximately 0.27 in 1970. Using the same proportion, total government consumption is projected for each year from 1980-84. This total is distributed among the sectors using the observed proportions in 1970. Final projections are shown in Table 4.17.

TABLE 4.17

PROJECTED GOVERNMENT CONSUMPTION (Rs MILLION AT 1970 PRICES)

	1980	1981	1982	1983	1984
1. Tea & Rubber	3	3	4	4	4
2. Other Agriculture	32	33	35	37	39
3. Light Manufacturing	55	58	61	64	68
4. Modern Industry	74	78	82	87	91
5. Mining & Construct.	145	153	161	169	178
6. Services	235	248	260	274	289
TOTAL	544	573	603	635	669

4.5.3 Exports

Exports are projected on the basis of the growth rates expected in PIP. PIP export projections are shown in Table 4.18.

TABLE 4.18

EXPORT PROJECTION GIVEN IN THE

PUBLIC INVESTMENT PROGRAMME

(value at current prices in million of US $)

	1979	1980	1984
1. Tea volume Mn. Kg	187	185	210
value	367	356	490
2. Rubber volume Mn. Kg	128	155	150
value	160	249	316
3. Coconut volume Mn. nuts	537	550	815
value	83	91	188
4. Gems-value	31	77	90
5. Petroleum-value	123	191	327
6. Industrial goods-value	115	182	443
7. Other - value	101	154	285
Total value	980	1300	2139

Using the information given in Table 4.18 average growth rates (in real terms) of exports are estimated and are shown in Table 4.19.

TABLE 4.19

EXPORTS: ANNUAL AVERAGE GROWTH RATES (IN REAL TERMS) IMPLICIT IN PUBLIC INVESTMENT PROGRAMME

(percentages)

	1980	1980-1984	1979-1984
1. Tea	-1.07	3.22	2.35
2. Rubber	21.09	-0.82	3.22
3. Coconuts	2.42	10.33	8.70
4. Gems	136.55 (149.39)*	-9.17 (3.98)*	10.66 (23.76)*
5. Industrial (Petroleum + industrial)	43.92 (56.76)*	6.72 (19.87)*	13.37 (26.47)*
6. Other	39.63 (52.47)*	3.49 (16.64)*	9.96 (23.06)*

* Growth rates in values

In case of gems, petroleum and industrial goods and other exports real growth rates are obtained by deducting the projected annual average increase in prices from the growth rates in value terms. Annual average price increases for the period 1979-84 are given in PIP, specifically for tea, rubber, coconut and all exports. Moreover the information given in Table 4.18 is sufficient to obtain estimates of price increases in 1980 and projected average annual increases for 1980-84.

These estimates are shown in Table 4.20.

TABLE 4.20

AVERAGE ANNUAL PRICE CHANGES

(Percentages)

	1980	1980-84	1979-1984
1. Tea	-1.95	4.94	3.60
2. Rubber	28.52	7.01	11.20
3. Coconuts	7.05	8.66	8.30
4. Other exports	12.84	13.15	13.10
5. All Exports	(9.00)	(9.00)	(9.00)

Price changes for other exports are not given in PIP. However given the average price increases for tea, rubber and coconuts, an average overall price increase of 9% implies 13.10% average annual price increase for other exports for the period 1979-84. This rate is derived using the composition of exports observed in 1979 (i.e. Tea 37%, Rubber 13% and coconuts 7%) as weights. Similarly price increases of other exports for 1980 and 1980-84 are derived assuming an overall price increase of 9% per annum.

Now it can be seen from Table 4.19 that PIP projection of growth rates for 1980 are rather surprisingly high, except for tea and coconuts. According to PIP projections rubber export (volume) will increase by 21.09% in 1980 and then would decline annually by 0.82%. Similarly for gems, petroleum, industrial and other exports a large jump can be seen in 1980 while the growth after 1980 is relatively marginal and in fact negative for gem exports. Therefore, we consider PIP export projections for 1980 as unrealistic and ignore them. We use the annual average growth rates for 1979-84 given in PIP to project exports for each year from 1980-1984.

Using the trade statistics given in CBRE (Tables 7.3 and 73) we compile Table 4.21 which shows exports of 1979 by their industrial origin both at current and constant (1970) prices. In estimating the values at constant prices, values at current prices of tea, rubber and coconuts are deflated by respective export price indices (CBRE, Table 65) All other exports except mining are deflated by the price index for 33 minor (export) products. For mining, implicit GDP price deflator for mining and quarrying is used.

TABLE 4.21

COMPOSITION OF COMMODITY EXPORTS - 1979

(Rs. million)

	at current prices		at 1970 constant prices	
1. Tea & Rubber		8213		1354
Tea	5722		995	
Rubber	2491		359	
2. Other Agriculture		2524		325
Coconuts	1699		190	
Minor Agric.	825		135	
3. Light Manufacturing		1598		262
4. Modern Industry		2004		328
5. Mining (including gem)		625		430
TOTAL:		14964 *		2699

* excluding unclassified exports of Rs. 309 mn.

Now using the 1979 exports at constant prices as the base, we apply the average annual growth rates of exports for 1979-84, to obtain projections of commodity exports for each year from 1980 to 1984. These projections are shown in Table 4.22.

PIP does not provide any specific projections on exports of services. However, it projects an increase in earnings from tourism from U.S. $68 million in 1979 to U.S. $230 million in 1984, which represents an annual average increase of 27.6%. This provides some indication of the growth in exports of services as tourism alone forms a larger portion (44% in 1979) of export of services. Therefore, considering the projected 9% annual average increase in export prices, we assume exports of services to grow at an annual average rate of 18.6% in projecting the export of services at constant prices, for each year from 1980 to 1984. In 1979, export of services was an estimate of Rs. 2378.2 million which was Rs. 370.9 million at 1970 constant prices.[1)] This estimate of exports of services for 1979 at constant prices is taken as the base for the projection. These projections are also shown in Table 4.22.

---

1. The deflator used was the price index for all exports.

TABLE 4.22

PROJECTED EXPORTS

(Rs. millions at 1970 prices)

	1980	1981	1982	1983	1984
1. Tea & Rubber	1389	1424	1462	1500	1539
Tea	1018	1042	1067	1092	1118
Rubber	371	382	395	408	421
2. Other Agriculture	355	387	423	462	505
Coconuts	207	224	244	265	288
minor agric.	148	163	179	197	217
3. Light Manufacturing	297	337	382	433	491
4. Modern Industry	372	422	478	542	614
5. Mining	476	527	583	645	714
Total Commodity	2889	3097	3328	3582	3863
6. Services	440	522	619	734	870
Total exports	3329	3619	3947	4316	4733

Projections given in Table 4.22 are at constant market prices. However, to be consistent with the 1970 data base, which was used in deriving most of the parameters of the model, exports should be expressed net of taxes and trade and transport margins should be removed from each of the first five sectors and included in the service sector. These adjustments are done on sectoral basis, according to the ratios implicit in the unpublished data used in the compilation of SAM for 1970 in PR.[1)]

1. Original work sheets were made available to me by Dr. J.I. Round, a co-author of PR.

These adjusted export projections and export taxes are given in Table 4.23. It should be noted that in balance of payments constraints, total exports specified for each year, i.e. $i'\bar{E}(t)$ are those given in the final row of the table which include export tax and represent foreign exchange available through exports.

TABLE 4.23

PROJECTED EXPORTS AT PRODUCER PRICES, $\bar{E}(t)$

AND EXPORT TAX, $t_e'\bar{E}(t)$

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
1. Tea & Rubber	1051	1078	1107	1135	1165
2. Other Agriculture	299	327	357	390	426
3. Light Manufacturing	207	234	266	301	341
4. Modern Industry	294	334	378	429	486
5. Mining & Const.	335	371	410	454	502
6. Services	809	924	1059	1215	1400
Export tax, $t_e'\bar{E}(t)$	334	351	370	392	413
Total Exports, $i'\bar{E}(t)$	3329	3619	3947	4316	4733

4.5.4 Public Investment on Social & Economic Overhead Capital

Rudra (1975) considers investment in the following areas as social and economic overhead investments.

1. education and health
2. residential housing, civic and municipal construction
3. roads, bridges, ports, airports, shipping, airways etc.
4. defence
5. civil administration
6. scientific research
7. exploration for natural resource.

To the above list we add large irrigational work and land development projects as well.

PIP provides a detailed list of public investment and their annual phasing. We examined the list carefully and identified the public overhead investment according to the above definition. Accordingly we identified that public overhead investment occurs in only three of our six sectors, namely, other agriculture, mining and construction and services. Our next step was to estimate deliveries required from each of the capital goods producing sectors to fulfil these overhead investments. For this purpose we assumed that these deliveries are proportional to the proportions given in the capital proportion matrix P.

Our next problem was to express these overhead investments at 1970 prices. PIP assumes 10% annual inflation rate for the period 1979-84. Using this rate we first expressed them at 1979 prices. Then Modern Industry Component of the investment was deflated by the import price index for investment goods. Construction and Service components were deflated by respective implicit GDP price deflators for construction and wholesale & retail trade.

Final results i.e. the deliveries for social and economic overhead investments at constant (1970) prices are shown in Table 4.24.

TABLE 4.24

PROJECTED DELIVERIES FOR SOCIAL AND ECONOMIC OVERHEAD INVESTMENTS.

(Rs. million at 1970 prices).

	1980	1981	1982	1983	1984
1. Tea & Rubber					
2. Other Agriculture					
3. Light Manufacturing					
4. Modern Industry	759.30	717.61	725.86	669.62	538.62
5. Mining & Const.	949.61	1079.33	1107.0	1106.22	904.21
6. Services	148.27	157.70	162.14	158.56	128.10
TOTAL:	1857.18	1954.64	1995.00	1934.40	1570.93

4.5.5 Net Foreign Capital Inflows

PIP projects Sri Lanka will receive Rs. 10876 mn in 1980 and Rs. 16627 million in 1984 as net foreign financial inflows. Altogether it expects to receive Rs. 68109 million for the period 1980 to 1984.

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This indicates an annual growth in net foreign financial inflows of approximately 11.2% (nominal). To be approximately consistent with these projections, for most of our solutions, net foreign capital inflows are set at Rs. 1070 million (at 1970) prices.[1),2)]

4.6 <u>Initial and Terminal Capital Stocks</u>

Initial capital stocks and capital in process should be estimated based on whatever the information available. They are the results of events in the pre plan period. However, since we do not have detailed empirical information with which to estimate the initial capacities and capital goods in process, following Eckaus and Parikh (1968), a somewhat arbitrary procedure is adopted to overcome the problem. Initial conditions are projected using the output levels in the pre plan period $\bar{X}(0)$, (i.e. 1979) and sectoral growth rates, e_0. It is also assumed that output levels in the preplan year (1979) from which initial capital stocks were projected are based on full use of existing capacity. An adjustment for less than full use of capacity in order to determine initial effective capital endowment could be significant. However, this adjustment could not be made because of the inadequacy of data on idle capacity.

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1. In arriving at this figure current values were deflated by the price index for all imports.

2. The consequences of changes in the availability of foreign assistance are analysed in an alternative solution.

The latest year for which sectoral output levels are available for Sri Lanka is 1970. However, value added by each sector is estimated and published by the Central Bank of Ceylon for subsequent years (CBRE). From these estimates of value added, it should have been possible to estimate sectoral output levels for 1979, using the value added coefficients observed in 1970. However, such a procedure is not practicable due to the differences in the valuation techniques adopted by the Central Bank before and after 1978, in estimating gross domestic product.[1)] Therefore, gross value of output levels for 1979 are estimated applying the growth rates in value added (at 1970 constant prices) to the 1970 gross value of output levels. These growth rates are shown in Table 4.25 along with the respective value added figures.

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1. These differences are outlined in Central Bank of Ceylon (1978,pp.22-25).

TABLE 4.25

GROSS DOMESTIC PRODUCT (NEW SERIES) - CENTRAL BANKS ESTIMATES

FOR 1970, 1979 AND IMPLIED PIP PROJECTIONS FOR 1984.

(Rs. millions at 1970 prices)

	1970	1979	Growth rates from 1970-79 %	PIP projected annual growth rates 1979-84 % *	Implied PIP projections for 1984
1. Tea & Rubber	1468	1411	-3.8828	(1.6284)	1529.69
Tea-growing	423	412	-2.6005	1.9	452.66
Rubber-growing	233	223	-4.2918	0.5	228.63
Tea & Rubber proc.	812	776	-4.4335	1.8	848.40
2. Other Agriculture	3076	3987	29.6164	(5.6049)	5236.80
coconuts	535	519	-2.9906	2.8	595.84
paddy	951	1132	19.0326	6.0	1514.87
other	1590	2336	46.9182	6.0	3126.09
3. Industry	1385	1883	35.9567	(7.6061)	2716.66
coconut processing	81	101	24.6914	1.8	110.42
other	1304	1782	36.6564	7.9	2606.24
4. Mining & Const.	839	1612	92.1335	(14.7793)	3211.31
Mining	95	652	586.3158	15.2	1322.85
Construction	744	960	29.0323	14.49	1888.46
5. Services	6419	9608	49.6806	5.3	12438.70
Gross Domestic Product	13187	18501	40.2973	6.3#	25133.16

* Brackets are used to indicate growth rates implicit, but not specifically given in PIP.

\# Growth rate given in PIP is 6.0%. However, application of sectoral growth rates given in PIP results in a 6.3% growth in GDP.

As can be seen from Table 2.25, Central Bank does not provide estimates of value added in Light Manufacturing and Modern Industry separately. Only the overall industrial growth is indicated. (3.5 percent per annum from 1970 to 1979). The same growth rate can only be applied to both Light Manufacturing and Modern Industries, if it can be assumed that there has not been a change in the shares of Light Manufacturing and Modern industries in total industrial output from 1970 to 1979, which is unrealistic. The fact that the share of modern industrial exports in total industrial exports has changed from 23% to 56% suggests that there should have been an increase in the share of Modern industrial output, that is, Modern industries should have been growing at a higher rate than Light Manufacturing industries. With the limited data available, the only way in which this fact can be taken into account is to use a proxy growth rate. In the event, the growth in industrial consumption of electricity and petroleum products were used as a proxy for the growth in Modern industries. However, this does not necessarily mean that Light Manufacturing industries do not consume electricity and petroleum products but the underlying assumption is that the consumption of these energy products by modern industry are relatively greater.

Industrial consumption of electricity has grown at an annual average rate of 9.3% while that of petroleum products has declined by 2.9% p.a. from 1970 to 1979. (CBRE tables 2.6 and 2.8). A growth rate for industrial energy consumption can be obtained from a weighted sum of the individual growth rates for electricity and petroleum products. These growth rates were combined using arbitrary weights of approximately 3 to 2, yielding an overall growth rate for industrial consumption of energy of 6.4%. Gross value of output of Modern industries in 1979 is then estimated by applying this growth rate to the gross value of output observed in 1970.

Output of Light Manufacturing and Modern industries as a whole is assumed to have grown by 3.5% p.a. from 1970 to 1979, which is the projected growth in value added by total industries. Then the output of Light Manufacturing industries is estimated as the residual between total industrial output and modern industrial output.

These estimated gross value of output levels are shown in Table 4.26. For easy reference, corresponding figures for 1970 are also shown.

For the terminal year (1984), projected growth rates in value added given in PIP are applied to the 1979 gross value of output levels to obtain target levels of output. PIP provides annual average growth rates for each sector for the period 1979-1984. These growth rates are shown in Table 4.25. Projected gross value of output levels in 1984 are shown in Table 4.26.[1)] Average annual growth rates in output from 1979 to 1984 are also given in Table 4.26. This same set of growth rates are taken as initial (e_0) and post-terminal (e_τ) growth rates.

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1. As PIP does not provide a detailed classification of industries same growth rate (i.e. 7.6061%)is applied for both Light manufacturing and Modern industries.

TABLE 4.26

GROSS VALUE OF OUTPUT IN 1970, 1979 AND 1984.

(Rs. million at 1970 prices)

	1970	1979 $\underline{X}(0)$	1984 $\overline{X}(T)$	Average Annual growth rates from 1979 to 84 $e_0=e_\tau$ (%)
1. Tea & Rubber	1238	1189.93	1290.02	1.6284
2. Other Agriculture	3556	4620.49	6076.82	5.6325
coconuts	577	559.74	642.62	2.8
paddy	1133	1348.64	1804.78	6.0
other	1846	2712.11	3629.42	6.0
3. Light Manufacturing	3365	4021.03	5801.25	7.6061
4. Modern Industry	1427	2494.01	3598.18	7.6061
5. Mining & Const.	2014	3200.57	6341.78	14.6560
Mining	108	741.22	1503.87	15.2
Construction	1906	2459.35	4837.91	14.49
6. Services	4736	7088.87	9177.39	5.3

4.7. Concluding Remarks

Our main source of data has been the Pyatt and Roe (1978). In many cases we directly estimated coefficients from their work. Whenever possible, an attempt was made to use recent data at least on a rough basis. Yet the major technical coefficients are those estimated for 1970, particularly the input-output coefficients and the capital coefficients matrix. Since we work in constant (1970) prices, this leads to the assumption that these coefficients have remained unchanged in volume term from 1970 to 1979 and would remain so until 1984. Considering the distribution of income between the poor and the rich, we again used 1970 ratios and depended upon Tyler and Roe (1977). It may well be the fact that these ratios have changed since 1970 and thus a new set of estimates is required. We identify this as a very useful research project to be undertaken in the future.

No specific study is undertaken on gestation lags in capital projects. Instead, investment lag proportions matrices were estimated on plausible assumptions. Import coefficients were estimated both for 1970 and 1979. They will be used in alternative solutions. Exports, Government consumption and public overhead investment were estimated in such a way as to be consistent with the expectations of the Public Investment Programme. Pre-plan output levels were estimated applying growth rates in value added to 1970 output levels. Targetted output levels were estimated from projected growth rates in value added. In estimating initial capital stocks full use of capacity and sectoral growth rates were assumed.

Our examination of data suggests the need to develop a new data base. Results obtained from the use of present data base should be interpreted with due caution.

CHAPTER 5.

Basic Features of the Model Solutions.

5.1 Introduction.

"The more recent trend in development theory is to abandon the search for completely general results in order to work with models whose properties can be derived by statistical estimation. This approach recognizes the need to disaggregate an economy into several sectors to reflect differences in production and demand functions as well as in trading possibilities. This formulation has been called, somewhat misleadingly, a 'planning model', even though it has been used more for analitical purposes than actual planning." Chenery (1979 p.46).

Chenery's above words outline the aims for which a planning model is used. The aim of a planning model is not necessarily to provide a complete development plan, rather it aims at assisting the preparation of a sound plan. Most importantly, it can be used to examine the effects of various policy measures. This chapter and the next two chapters present model solutions for Sri Lanka and examines their policy implications. The solutions are calculated using the targets implicit in the Public Investment Programme (PIP) which were shown in Chapter 4. Our aim is not merely to examine the consistency and feasibility of the PIP targets, but to examine the sensitivity of the results to alternative estimates of production, foreign financial assistance and export prospects and thereby to examine the various policy implications. Basically the implications of public overhead investments, the relative importance of foreign financial assistance and domestic savings, and the distributional implications of the model solutions are investigated.

The data base for the model solution was presented in detail in Chapter 4. All the parameters and exogenous values are as shown in Chapter 4 with the social discount rate fixed at 0.10. Given these parameters and exogenous values, no feasible solution can be found for the targets implicit in the PIP.[1)] This suggests an inconsistency between the PIP targets and the availability of domestic and foreign resources. The targets are too optimistic and technically not consistent with available resources. Without a feasible solution, it is not possible to examine the binding constraints for development and an optimal development path. Therefore it is necessary to find the conditions under which a feasible solution could be obtained. One possibility is to change the critical production coefficients and other relationships (i.e. capital output ratios and investment lags) until a feasible solution is obtained. The other is to scale down the targets. The procedure we followed was to reduce the public overhead investments systematically. By this means we managed to obtain an optimal solution by reducing the public overhead investment up to the 37.18% of the target level each year. Considering the production coefficients and relations, we found that an optimal solution can be found at 51.00% of the target

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1. All the results present in the study are obtained using the TEMPO Computer package available at the computer unit of the Warwick University. This package has extensive facilities for piece-wise linear approximation of non linear functions. For details see Burroughs Corporation (1975).

level of public overhead investment if the capital output ratio of 'Modern Industry' were 10% lower than the reference value reported in Chapter 4. Again another 10% reduction in the same capital output ratio would provide an optimal solution at 65.04% of the target level of the public overhead investment. Therefore it is quite apparent that an optimal solution could be obtained at higher levels of public overhead investment if the capital output ratio in the modern industry were lower. However, even though capital output ratios we used may not be fully accurate, it is unlikely that they have error margins of more than 20%. On the other hand, the investment lags we used were very optimistic compared with the three year lags used by Eckaus and Parikh (1968) for India.

Given these facts, it seems that we have sound reasons to question the feasibility of the targets implicit in the PIP. Even though we obtained an optimal solution at 37.18% of the target level of public overhead investment, it does not mean that at the end of the planning period there would necessarily be an under-achievement of public overhead investment by 62.82% and the rest of the targets would be realised completely. In reality, the government may be able to achieve its public overhead investment targets by more than 37.18%, but its effects will be felt in reduced level of activities in the other sectors of the economy, and high inflationary pressure would prevail and the economy may end up in a foreign exchange crisis.

However, the solution with 37.18% of the target level of public overhead investment is taken as our reference solution to discuss the operation of the model. This should not be interpreted as the best possible solution given the production structure, technical and behavioural relations, and the targets.

As one of the purposes of the study is to examine the implications of public overhead investments, it will be necessary to compare the reference solution with the results of the model solution with no public overhead investment. Therefore, selected details of the solution with no public overhead investments are also presented, and will be referred to as the alternative reference solution.

This chapter presents the sectoral details of the reference solution and compares them with those of the alternative reference solution in order to highlight the way in which the pattern of output and capital formation in the reference solution was influenced by the exogenously imposed public overhead investments.

For each year, sectoral levels of output, capital stock, newly created capacity, competitive imports and shadow prices are directly given in the solutions. Other details presented are implicit in the solutions.

5.2 Gross Domestic Outputs.

Gross domestic output levels and growth rates in the reference solution are reported in Table 5.1. As can be seen, growth rates fluctuate from year to year. No sector exhibits steady year to year growth, either at a linear or an exponential rate. The composition of the target levels of capacities are not quite the same as the composition

TABLE 5.1

GROSS DOMESTIC OUTPUTS AND SECTORAL GROWTH RATES IN THE REFERENCE SOLUTION

(Rs million at 1970 prices)

	1979 (Pre Plan Year)	1980	%	1981	%	1982	%	1983	%	1984	%	Compound Growth rate from 1979 to 1984 %
1. Tea & Rubber	1190	1170	-1.68	1206	3.08	1254	3.98	1291	2.95	1326	2.71	2.19
2. Other Agriculture	4620	4881	5.65	5155	5.61	6378	23.72	6826	7.02	6619	-3.03	7.46
3. Light Manufacturing	4021	4327	7.61	4656	7.60	6026	29.42	6452	7.07	6257	-3.02	9.25
4. Modern Industry	2494	2684	7.62	2888	7.60	2800	-3.05	3180	13.57	3852	21.13	9.08
5. Mining & Construction	3201	2476	-22.65	2690	8.64	2568	-4.53	2684	4.52	2845	6.00	-2.33
6. Services	7089	6723	-5.16	7318	8.85	8083	10.45	8724	7.93	9531	9.25	6.10

of initial capacities. Therefore, under such circumstances, uniform growth in all sectors cannot be expected.

Given the fact that the objective function is defined in terms of the disposable incomes of the poor and the rich households and that it includes higher weights on the utilities of the poor households, one could expect the optimisation procedure to place more emphasis on those sectors whose income coefficients for the poor are relatively higher. In this respect Tea and Rubber and Other Agriculture get the highest rank.[1)] On the other hand, Light Manufacturing records the highest propensity to consume by the poor and the second highest by the rich. Given these facts it is reasonable for the model solution to generate relatively higher growth rates in Other Agriculture and agriculture-based Light Manufacturing. Despite this fact, the model solution yielded a substantially high annual average growth in Modern Industry, which is only slightly lower than the annual average growth rate recorded in Light Manufacturing sector. This is mainly due to its importance as a capital goods supplying sector. Because of this reason, growth in all other sectors has to be supported by the growth in Modern Industry. However, this may not be necessarily true if foreign exchange is sufficiently available to import the requirements of modern industrial goods. Considering the non competitive import coefficient which is the largest among all sectors and the capital output ratio which is the highest among importable goods producing sectors, it may be relatively

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1. See Table 4.13.

more advantageous to import modern industrial goods (to the extent allowed by the availability of foreign exchange). The important point is that the public overhead investment imposes a heavy exogenous demand on Modern Industry which cannot be met unless the domestic output is increased substantially. This point can be clarified by looking at the gross domestic outputs and growth rates in the alternative reference solution which are reported in Table 5.2.

Compared with the annual average growth rate of 9.08% in Modern Industry in the reference solution, the alternative reference solution generates only 3.70% annual average growth in Modern Industry but relatively higher growth rates in Other Agriculture and Light Manufacturing. Output levels of Modern Industry are exactly the same up to the third year in both the solutions. But compared with the 13.57% and 21.13% growth of Modern Industry in the fourth and fifth years in the reference solution, the alternative reference solution gives only 10.18% growth in the fourth year and a decline of 3.05% in the fifth year. This points to the fact that the exogenously-imposed public overhead investment forces the model to give relatively higher growth in Modern Industry at a cost of reduced growth in the other sectors and the relatively higher growth in Modern Industry in the reference solution is not induced by the endogenous investment requirements to facilitate the growth in the other sectors.

This point is further highlighted in a comparison of the share of competitive imports in the total supplies in the solutions with and without public overhead investment. In the reference solution, the share of competitive imports in total supply of modern industrial output,

TABLE 5.2

GROSS DOMESTIC OUTPUTS AND SECTORAL GROWTH RATES IN THE ALTERNATIVE REFERENCE SOLUTION

(Rs million at 1970 prices)

	1979 (pre plan Year)	1980	%	1981	%	1982	%	1983	%	1984	%	Compound Growth rate from 1979 to 1984 %
1. Tea & Rubber	1190	1173	-1.43	1229	4.77	1254	2.03	1301	3.75	1334	2.54	2.31
2. Other Agriculture	4620	4881	5.65	5155	5.61	6140	19.11	8169	33.05	7444	8.87	10.01
3. Light Manufacturing	4021	4327	7.61	4656	7.60	6654	42.91	6453	-3.02	7144	10.71	12.18
4. Modern Industry	2494	2684	7.62	2888	7.60	2800	-3.05	3085	10.18	2991	-3.05	3.70
5. Mining & Constructon	3201	3118	-2.59	2621	-15.94	2409	-8.09	2355	-2.24	2407	2.21	-5.54
6. Services	7089	6856	-3.29	7236	5.54	8057	11.35	9068	12.55	9965	9.89	7.05

initially rises from 17.50% in 1980 to 29.18% in 1982 and then steadily drops to 16.34% by 1984. In the alternative reference solution, it rises from 13.71% in 1980 to 33.98% by 1984. On the other hand, the share of competitive imports in the total supply of Light Manufacturing goods in the reference solution, first declines from 18.59% in 1980 to 8.30% in 1982 and then increases steadily to up to 13.14% by 1984. Whereas in the alternative reference solution, it declines from 20.65% in 1980 to zero percent in 1982, then increases to 11.69% in 1983, and finally drops to 5.82% in 1984, which is much lower than the share in 1980. Therefore it appears that the choice to develop Modern Industry at a relatively higher rate is largely synonymous with the choice to undertake public overhead investments.

Higher growth in Modern Industry seems to have been achieved mainly at a cost of relatively lower growth in Light Manufacturing and Other Agriculture. The alternative reference solution records the highest annual average growth of 12.18% in Light Manufacturing compared to 9.25% in the reference solution. Similarly, it records a 10.01% annual average growth in Other Agriculture compared with 7.46% in the reference solution. Tea and Rubber grows at the possible maximum rate in the alternative reference solution while the annual average growth rate is slightly lower in the reference solution. Growth in this sector is largely pre-determined by the exogenously specified levels of exports.

The services sector has the highest propensity to consume by the Rich and second highest by the poor. In addition, it also provides supporting services for the other sectors. In terms of the income coefficients for the poor it has the third highest rank while it has the highest rank in terms of the income coefficients for the rich. These facts explain the growth in service sector. However, even in this sector, average annual growth is relatively low compared with the corresponding growth rate in the alternative reference solution.

The behaviour of Mining and Construction sector looks somewhat erratic and deserves an explanation. At first sight, the initial (1979) output and capacity in this sector seems very large compared with our model solutions over the period 1980 to 1984. This is due to the heavy boost in construction activities after the liberalization of imports in November 1977. Until November 1977, there was a heavy pent-up demand for construction due to the scarcity of inputs caused by import controls. Therefore, 1978 and 1979 recorded massive growth in construction. (For example, value added in construction, at 1970 prices, increased by 28.27% in 1978 and 20.91% in 1979). This growth was heavily augmented by the public sector overhead investment expenditure and the PIP projected an impressive growth in construction considering the public overhead investments. Such a high growth is notreflected in the model solutions because even the reference solution incorporates only 37.18% of the target level of public overhead investments, each year.

The model solution for the first year represents a 1.68% decline in the output of Tea and Rubber and 5.16% reduction in the output of Services. This is because we have not specified any constraints in the model that require output levels to be higher than the pre-plan levels. The imposition of such constraints, though not impossible, would reduce the flexibility of the model and would obviously reduce the value of the maximand. The present specification gives the model the freedom to select its own starting point subject only to constraints specified by the initial capacity levels.

Shadow prices of the outputs are shown in Table 5.3. These are the shadow prices corresponding to the production accounting relationships. These prices indicate the value to the maximand of an additional unit of output. As a whole, shadow prices are rather low. This should be expected, considering the scale of the objective function which expresses the values in natural log terms.

TABLE 5.3. Shadow Prices of Gross Domestic Outputs in the Reference Solution

	1980	1981	1982	1983	1984
1. Tea & Rubber	-	0.00011	0.00017	0.00026	0.00023
2. Other Agriculture	0.00025	0.00036	-	0.00013	0.00015
3. Light Manufacturing	0.00025	0.00036	0.00013	0.00017	0.00015
4. Modern Industry	0.00025	0.00036	0.00013	0.00017	0.00015
5. Mining & Construction	-	-	-	-	-
6. Services	-	-	0.00038	0.00018	0.00015

5.3 Capital Stock.

Further insight into the model solution can be obtained by examining the availability and intensity of use of capital stock which are disclosed in Tables 5.4, 5.5, 5.6 and 5.7. These tables show, respectively, the available capital stock, capital stock used, ratio of capital stock used to available capital and new capital matured in each year. Similar information pertaining to the alternative reference solutions are also shown in Tables 5.8, 5.9, 5.10 and 5.11 for comparison. However, following comments refer to the reference solution, unless specifically mentioned otherwise.

The information exhibited in these tables closely parallel the results for gross output levels and their growth rates. Except for Mining and Construction, all sectors operate at their full capacity in most of the years. Not one single sector overachieves the target level of post terminal capital stock. This indicates the constraints which the targets impose on the system

Parallel to the high growth in its output, the Modern industrial sector operates at its full capacity throughout the planning period. New capacities are added every year except in the third year. By the fifth year, the accumulated capital stock is so large that it required only Rs 274 mn additional capacity in the sixth year to achieve the target specified for that year. In contrast, in the alternative reference solution, target level of capital stock is achieved largely by creating additional capacities in the post terminal years. Within the planning period, capacity is augmented only in the second and fourth years. Even

TABLE 5.4

AVAILABLE CAPITAL STOCK IN THE REFERENCE SOLUTION

(Rs million at 1970 prices)

	1980	1981	1982	1983	1984	1985	1986
1. Tea & Rubber	2761	2806	2862	2948	3028	2993	3042
2. Other Agriculture	2328	2459	3357	3255	3157	3061	3234
3. Light Manufacturing	4184	4502	5827	6240	6050	6036	6496
4. Modern Industry	5379	5788	5613	6373	7721	7761	8351
5. Mining & Construction	2738	2763	2680	2599	2520	5426	6221
6. Services	17240	18154	18669	20148	22012	22319	23502

TABLE 5.5

CAPITAL STOCK USED IN THE REFERENCE SOLUTION

(Rs million at 1970 prices)

	1980	1981	1982	1983	1984	Target 1985	Stock 1986
1. Tea & Rubber	2671	2753	2862	2948	3028	2993	3042
2. Other Agriculture	2328	2459	3042	3255	3157	3061	3234
3. Light Manufacturing	4184	4502	5827	6240	6050	6036	6496
4. Modern Industry	5379	5788	5613	6373	7721	7761	8351
5. Mining & Construction	1847	2007	1917	2003	2123	5426	6221
6. Services	15527	16901	18669	20148	22012	22319	23502

TABLE 5.6

RATIO OF CAPITAL STOCK USED TO TOTAL CAPITAL IN THE REFERENCE SOLUTION

	1980	1981	1982	1983	1984	Ratio of Total Capital to Targets	
						1985	1986
1. Tea & Rubber	0.9674	0.9811	1.0000	1.0000	1.0000	1.0000	1.0000
2. Other Agriculture	1.0000	1.0000	0.9062	1.0000	1.0000	1.0000	1.0000
3. Light Manufacturing	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4. Modern Industry	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5. Mining & Construction	0.6746	0.7264	0.7153	0.7707	0.8425	1.0000	1.0000
6. Services	0.9006	0.9310	1.0000	0.20148	1.0000	1.0000	1.0000

TABLE 5.7

NEW CAPITAL ADDED IN THE REFERENCE SOLUTION

(Rs million at 1970 prices)

	1981	1982	1983	1984	1985	1986
1. Tea & Rubber	129	141	173	169	57	140
2. Other Agriculture	202	973	-	-	-	266
3. Light Manufacturing	445	1461	589	-	169	643
4. Modern Industry	572	-	931	1541	274	825
5. Mining & Construction	108	-	-	-	2982	959
6. Services	1436	1065	2045	2474	974	1860

TABLE 5.8

AVAILABLE CAPITAL STOCK IN THE ALTERNATIVE REFERENCE SOLUTION

(Rs million at 1970 prices)

	1980	1981	1982	1983	1984	1985	1986
1. Tea & Rubber	2761	2806	3063	2970	3086	2993	3042
2. Other Agriculture	2328	2459	2928	3896	3778	3663	3552
3. Light Manufacturing	4184	4502	6435	6240	6908	6699	6496
4. Modern Industry	5379	5788	5613	6183	5996	7761	8351
5. Mining & Construction	2738	2655	2575	2496	2421	5426	6221
6. Services	17240	18154	18608	20943	23016	22319	23502

TABLE 5.9

CAPITAL STOCK USED IN THE ALTERNATIVE REFERENCE SOLUTION

	1980	1981	1982	1983	1984	Target Stock 1985	Target Stock 1986
1. Tea & Rubber	2678	2806	2862	2970	3046	2993	3042
2. Other Agriculture	2328	2459	2928	3896	3550	3061	3234
3. Light Manufacturing	4184	4502	6435	6240	6908	6036	6496
4. Modern Industry	5379	5788	5613	6183	5996	7761	8351
5. Mining & Construction	2326	1956	1798	1757	1797	5426	6221
6. Services	15835	16712	18608	20943	23016	22319	23502

TABLE 5.10

RATIO OF CAPITAL STOCK USED TO TOTAL CAPITAL IN THE ALTERNATIVE REFERENCE SOLUTION

	1980	1981	1982	1983	1984	Ratio of Total Capital to Targets 1985	1986
1. Tea & Rubber	0.9699	1.0000	0.9344	1.0000	0.9870	1.0000	1.0000
2. Other Agriculture	1.0000	1.0000	1.0000	1.0000	0.9396	1.1967	1.0983
3. Light Manufacturing	1.0000	1.0000	1.0000	1.0000	1.0000	1.1098	1.0000
4. Modern Industry	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5. Mining & Construction	0.8495	0.7367	0.6982	0.7039	0.7423	1.0000	1.0000
6. Services	0.9185	0.9206	1.0000	1.0000	1.0000	1.0000	1.0000

TABLE 5.11

NEW CAPITAL ADDED IN THE ALTERNATIVE REFERENCE SOLUTION

(Rs million at 1970 prices)

	1981	1982	1983	1984	1985	1986
1. Tea & Rubber	129	342	-	206	-	140
2. Other Agriculture	202	544	1057	-	-	-
3. Light Manufacturing	445	2069	-	858	-	-
4. Modern Industry	572	-	741	-	1947	825
5. Mining & Construction	-	-	-	-	3078	959
6. Services	1436	1004	2899	2707	-	1860

in the fourth year, additional capacity created is 20.41% lower than that in the reference solution. This also highlights the specific feature of the Modern Industry in the reference solution and the way it was affected by the public overhead investment.

Light Manufacturing also operates at full capacity throughout the planning period. New capacities are added every year except the fifth year. However, capacity created within the planning period is not so large that additional capacities had to be formed in the postterminal years to realise the specified targets. This pattern of capacity formation is due to the influence of public overhead investment which force the model solution to place more emphasis on Modern Industry. In the alternative reference solution no capacities are created in the post-terminal years and the capacity created within the planning period is large enough not only to realise the targets, but also to overshoot the target specified for the sixth year.

Other Agriculture operates at full capacity in all the years except 1982. Excess capacity in 1982 is due to the fact that by 1982 a sufficiently large capital stock has been accumulated to meet the requirements of the following years and to achieve the target specified for the sixth year. If there were no public over-head investment, the model would have had a sufficient flexibility to build up an even larger capital stock within the planning period and would not only achieve the targets of postterminal capacity but would also overshoot them.

Tea & Rubber and Services operate at a little below the full capacity level in the first two years. Even though they do not operate at full capacities at the beginning, additional capacities are created in the second year as well. This is to fulfil the requirements of the following years in which the sectors operate at their full capacities. These are the only two sectors which accumulate new capacities in every year.

The Mining & Construction sector operates at below its full capacity level for similar reasons for the heavy drop in the output in the first year. New capacities are almost wholly added in the postterminal years, just to maintain the targets.

Tables 5.12 and 5.13 present the shadow rental prices of capital and shadow prices of new capital. The shadow rental price is zero whenever there is excess capacity in the sector, therefore it could be zero, even when the output produced with it has a non-zero shadow price. Shadow price of new capital corresponds to the capital accounting relationships in the model. As it was pointed out by Eckaus and Parikh (1968), at the start of the sixth year, that is at the end of the fifth year, the shadow price of new capital reflects neither the future usefulness, nor the productivity of this capital, but rather the cost in terms of value of the objective function which had to be foregone in order to create the amount of capital that the targets stipulated. This is because the post-terminal incomes and the consumptions are not included in the objective function explicitly. The present formulation is equivalent to having an objective function with weight of infinity on terminal capacity for values below the target levels, but with a weight of zero once the target levels are achieved.

TABLE 5.12

SHADOW RENTAL PRICES OF CAPITAL IN THE REFERENCE SOLUTION

	1980	1981	1982	1983	1984
1. Tea & Rubber	-	-	-	-	-
2. Other Agriculture	0.00047	0.00059	-	0.00019	0.00023
3. Light Manufacturing	0.00015	0.00017	0.00011	0.00010	-
4. Modern Industry	0.00011	0.00015	-	-	-
5. Mining & Construction	-	-	-	-	-
6. Services	-	-	0.00017	-	-

TABLE 5.13

SHADOW PRICES OF NEW CAPITAL IN THE REFERENCE SOLUTION

	1981	1982	1983	1984	1985	1986
1. Tea & Rubber	0.00057	0.00059	0.00056	0.00049	0.00034	-
2. Other Agriculture	0.00108	0.00051	0.00052	0.00034	-	0.00012
3. Light Manufacturing	0.00081	0.00066	0.00057	0.00048	0.00038	-
4. Modern Industry	0.00075	0.00062	0.00057	0.00051	0.00040	-
5. Mining & Construction	0.00041	0.00042	0.00044	0.00045	0.00042	-
6. Services	0.00071	0.00073	0.00058	0.00052	0.00042	-

Ratio of completed initial capital in process to initial available capital in process and the shadow price of initial capital in process are shown in Table 5.14. As can be seen, all sectors except Mining & Construction totally complete the initial capital in process. This highlights the strain which the initial conditions place on the system.

5.4 Imports.

In most of the sectors, production is not possible without imports. Non-competitive import coefficients specify these minimum requirements of imports. In addition, if foreign exchange is available after meeting non-competitive import requirements, domestic supply of the output of importable sectors can be supplemented by competitive imports. However, the present formulation of the model does not necessarily allocate all this uncommitted foreign exchange on competitive imports. The objective function is expressed in terms of the disposable incomes, and consumption is strictly related to incomes. Therefore, the levels of domestic output are determined so as to maximise the objective function. Foreign exchange is allocated to competitive imports as a supplementary means of meeting the demand requirements. This is in contrast to the simple aggregate consumption maximizing models where consumption is not related to incomes. In such models no foreign exchange will be left unused because it could always be used to import consumer goods and hence increase the maximand.

Details of imports are shown in Table 5.15. Available foreign exchange is fully used up in each year for importing the requirements of non competitive and competitive goods. The importance of foreign exchange

TABLE 5.14

RATIO OF COMPLETED INITIAL CAPITAL IN PROCESS TO INITIALLY AVAILABLE CAPITAL IN PROCESS IN THE REFERENCE SOLUTION

	Ratio	Shadow Price		Ratio	Shadow Price
1. Tea & Rubber	1.0000	0.00025	4. Modern Industry	1.0000	0.00035
2. Other Agriculture	1.0000	0.00083	5. Mining & Construction	0.2231	-
3. Light Manufacturing	1.0000	0.00043	6. Services	1.0000	0.00027

TABLE 5.15

DETAILS OF IMPORTS IN THE REFERENCE SOLUTION

(Rs million at 1970 prices)

	1980	1981	1982	1983	1984
1. Competitive Imports					
(1) Tea & Rubber	-	-	-	-	-
(2) Other Agriculture	121	209	-	-	290
(3) Light Manufacturing	1087	1150	600	594	1041
(4) Modern Industry	917	883	1858	1941	1212
(5) Mining & Construction	-	-	-	-	-
(6) Services	-	-	-	-	-
2. Total Competitive Imports	2125	2242	2458	2535	2543
3. Total Non Competitive Imports	2274	2447	2559	2851	3260
4. Total Imports	4399	4689	5017	5386	5803
5. Share of (2) in Total Imports (%)	48.31	47.81	48.99	47.07	43.82
6. Share of (3) in Total Imports (%)	51.69	52.19	51.01	52.93	56.18
7. Shadow Prices on Foreign Trade Balance Constraints	0.00025	0.00036	0.00013	0.00017	0.00015

TABLE 5.16.

DETAILS OF IMPORTS IN ALTERNATIVE REFERENCE SOLUTION

(Rs million at 1970 prices)

		1980	1981	1982	1983	1984
1.	Competitive Imports					
	(1) Tea & Rubber	-	-	-	-	-
	(2) Other Agriculture	194	196	452	-	-
	(3) Light Manufacturing	1239	1125	-	940	486
	(4) Modern Industry	687	923	1947	1633	2479
	(5) Mining & Construction	-	-	-	-	-
	(6) Services	-	-	-	-	-
2.	Total Competitive Imports	2120	2244	2399	2573	2965
3.	Total Non-Competitive Imports	2279	2445	2618	2813	2838
4.	Total Imports	4399	4689	5017	5386	5803
5.	Share of (2) in Total Imports	48.19	47.86	47.82	47.77	51.09
6.	Share of (3) in Total Imports	51.81	52.14	52.18	52.23	48.91
7.	Shadow Prices on Foreign Trade Balance Constraints	-	0.00013	-	-	-

in financing import requirements are indicated by the shadow prices of foreign trade balance constraints. These prices alone would not reflect the productivity of foreign exchange as we also have to consider the role of foreign exchange in supplementing domestic savings (see p.181.). As it can be seen, there is a tendency for the share of competitive imports in total imports, to decline, though it increased slightly in the second year. This decline is quite apparent in the fifth year in which domestic capacities are increased in Modern Industry and which reduce the competitive imports substantially. This also can be compared with the details of imports in the alterantive reference solution which is reported in Table 5.16. In this solution, the share of competitive imports in total imports reduces gradually and marginally up to the fourth year, reflecting mainly the reduction in the competitive imports of Light Manufacturing goods. But in the fifth year, it increases, compared with the decline in the reference solution, reflecting largely the competitive imports of Modern Industrial goods. This also confirms the specific behaviour of Modern Industry we observed in the output of and capital formation in this sector which was largely determined by the exogenously imposed public overhead investments.

CHAPTER 6 :

Macro Economic Comparisons of the Reference and Other Alternative Solutions

6.1 Introduction

The previous chapter examined the sectoral details of the reference solution with respect to the pattern of outputs and capital formation, and the way in which that particular pattern was influenced by the exogenously specified demands for public overhead investment . This chapter looks into the macro economic aggregates of Gross Domestic Product (GDP), consumption, savings, investments and the balance of payments. The particular importance of domestic savings and foreign financial assistance is analysed, emphasizing the way in which the solution is influenced by the public overhead investment.

The results are presented and interpreted in terms of the two gap model.[1] The two gap model identifies two limiting factors for economic growth:

(i) availability of imports

(ii) capacity to generate domestic savings to finance the required investment.

Assuming that the attainment of a target level of income requires a minimum level of imports and investment, the 'Trade Gap' is determined by the excess of imports over possible exports while the 'Savings Gap'

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1. For details see Chenery and Bruno (1962), Chenery and Strout (1966), and McKinnon (1964).

is given by the excess of investment over potential savings. In the expost sense, the two gaps are identical, but in the exante (planned) sense the two gaps may be different. In order to reach the target income, the larger of the two exante gaps must be filled by foreign capital inflows. Thus when the trade gap is dominating and foreign capital is forthcoming to provide the necessary foreign exchange, realised savings may fall below their potential level or new investment may go into less profitable projects. Conversely, when the savings gap is dominating foreign capital inflows will supplement the domestic savings and realised imports may exceed the minimum level required to realise the target level of income or export may be lower than the planned level.

Two gap analysis emphasises the dual role of foreign financial inflow, i.e. its role of financing the import requirements and supplementing domestic savings. Accordingly the shadow price of foreign exchange should be the sum of the shadow price on foreign trade balance constraint and the savings constraint (cf. Tendulkar 1968). In the reference solution, both trade and savings constraints are binding and carry their own shadow prices. These shadow prices and, accordingly, the implicit shadow price of foreign exchange are reported in Table 6.1.

TABLE 6.1

SHADOW PRICE OF FOREIGN EXCHANGE IN THE

REFERENCE SOLUTION

	1980	1981	1982	1983	1984
Shadow price associated with					
1. Foreign trade balance constraints	0.00025	0.00036	0.00013	0.00017	0.00015
2. Savings constraints	0.00029	0.00049	0.00048	0.00038	0.00035
Shadow price of foreign exchange	0.00054	0.00085	0.00061	0.00055	0.00050

6.2 Reference Solution

The Macro economic aggregates of the reference solution are shown in Table 6.2, within the framework of a two gap analysis.

TABLE 6.2

MACRO ECONOMIC AGGREGATES OF THE REFERENCE SOLUTION

(Rs. millions at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	15724	16828	18814	20154	21076
Plus Net Indirect Tax	2216	2373	2647	2849	3006
Gross Domestic Product at Market Prices	17940	19201	21461	23003	24082
Private Consumption:					
Poor Households	7017	7487	8527	9114	9372
Rich Households	4924	5278	5839	6259	6619
Aggregate Private Consumption at Producer Prices	11941	12765	14366	15373	15991
Plus Net Indirect Tax	163	175	197	210	219
Aggregate Private Consumption at Market Prices	12104	12940	14563	15583	16210
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	3282	3572	4067	4439	4732
Ratio of Savings to GDP at Market Prices (%)	18.29	18.60	18.95	19.30	19.65
Aggregate Investment	3834	4090	4526	4854	5112
Plus Indirect Tax	518	552	611	655	690
Aggregate Investment at Market Prices	4352	4642	5137	5509	5802
Ratio of Investment to GDP at Market Prices (%)	24.26	24.17	23.94	23.95	24.09
Savings Gap	1070	1070	1070	1070	1070
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f)	4399	4689	5017	5386	5803
Trade Gap	1070	1070	1070	1070	1070

The Gross domestic product in each year is the sum of value added by each sector, which is calculated applying the value added ratios to the sectoral output levels generated by the model solution, and the value added by the government which is specified exogenously. These sums are subsequently adjusted for net indirect taxes to derive the planned gross domestic products at market prices. The model solution directly provide the optimum levels of disposable incomes of the poor and the rich households for which respective aggregate consumption ratios are applied to obtain the private consumption levels. Again, projections at market prices are derived adjusting the figures for net indirect taxes. Public expenditure represents the current expenditure on public consumption and salaries and wages paid to the employees in the public service which are specified exogenously. Total savings are the residuals of gross domestic products at market prices after subtracting both the private and public current expenditures. These levels of savings are comparable with the specified parameters of the model pertaining to the savings ratios of the poor and the rich households and other institutions. Investment levels are the minimum required to generate the planned incomes. The savings gap represents the excess of investments over the savings which has to be financed by the inflow of foreign capital. Imports represent the minimum import requirements to realise the planned incomes while exports are specified exogenously. The trade gap represents the excess of imports over the exports which has to be financed by the inflow of foreign capital.

In this solution, both the savings and foreign exchange constraints are binding. Therefore, both the trade and the savings gaps are equal in each year. The ratio of total savings to GDD (at market prices) increases marginally from 18.29% in 1980 to 19.65% by 1984. The ratio of investment to GDP (at market prices) remains at approximately 24% throughout the planning period. The difference between the investment and savings ratios is the ratio of savings gap to GDP (at market prices) a gap which has to be financed by the foreign capital inflows. Therefore the importance of foreign capital inflows is highlighted in this solution. Foreign capital inflows are required not only to finance the imports but also to supplement domestic savings. Without the foreign financial assistance planned levels of incomes and consumptions are beyond the frontier of feasibility.

6.3 Alternative Reference Solution

Given the results of the reference solution, it is useful to examine the way in which this solution was influenced by the public overhead investment . Table 6.3 presents the macro economic aggregates of the alternative reference solution.

TABLE 6.3 MACRO ECONOMIC AGGREGATES OF THE ALTERNATIVE REFERENCE SOLUTION

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	16192	16742	18627	21373	21731
Plus Net Indirect Tax	2160	2359	2700	2749	2990
Gross Domestic Product at Market Prices	18352	19101	21327	24122	24721
Private Consumption:					
Poor Households	7209	7461	8432	9839	9839
Rich Households	5047	5247	5796	6559	6788
Aggregate Private Consumption at Producer Prices	12256	12708	14228	16398	16627
Plus Net Indirect Tax	168	174	195	224	228
Aggregate Private Consumption at Market Prices	12424	12882	14423	16622	16855
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	3374	3530	4073	4519	4726
Ratio of Savings to GDP at Market Prices (%)	18.38	18.48	19.10	18.73	19.12
Aggregate Investment	3148	4034	4531	3965	4855
Plus Net Indirect Tax	425	545	612	535	655
Aggregate Investment at Market Prices	3573	4579	5143	4500	5510
Ratio of Investment to GDP at Market Prices	19.47	23.97	24.11	18.66	22.29
Savings Gap	199	1049	1070	-19	784
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f)	4399	4689	5017	5386	5803
Trade Gap	1070	1070	1070	1070	1070

As it can be seen, this solution provides a better level of performance compared to the reference solution. For example, it generates a discounted sum of incomes (GDP at producer prices) of Rs. 77707 mn which is 2.10% higher than that in the reference solution. Similarly it provides a discounted sum of consumption of Rs. 59244 mn (at producer prices) which is 2.34% higher than that in the reference solution. This higher level of performance is achieved at a relatively lower level of investment. The discounted sum of investment at Rs. 16855 mn is 8.55% lower compared to that in the reference solution. In the reference solution, level of investment is higher, first because of the exogenously specified public overhead investment and second, due to the fact that the demand generated by these public investments, forced the model to operate Modern Industry (which is relatively more capital intensive) at a higher level. If the public overhead investment did not force the model to emphasise Modern Industry, it would have tended to operate other agriculture at a higher level. This has a relatively higher value added coefficient. Furthermore, public overhead investment also utilized a portion of limited investible resources without actually contributing to the productivity within the planning period.

The differences in the average savings ratios in this solution and the reference solution are marginal. However, as the average investment ratios are lower (except in the third year) compared with the reference solution, investment is largely financed by domestic savings. Both the trade and the savings gaps are identical only in the third year. In all the other years, the savings constraint is not binding and therefore the trade gap is dominant. In the fourth year the available domestic savings is more than adequate to finance the investments in that year. Therefore it is quite apparent that if the public overhead investments were not incorporated then the growth is largely constrained not by the lack of domestic savings but by the availability of foreign exchange.

This solution provides some insights into the influence of foreign financial assistance on domestic savings as well. The situation is quite clear when both the gaps are identical. Then, foreign financial assistance would invariably supplement domestic savings in financing investments. But in the present solution the trade gap is dominating in all years except the third. However, expost, the two gaps must be identical. Therefore, there has to be some adjustment mechanism to make the savings gap as large as the trade gap. A reduction in the trade gap has been ruled out since it is not possible (under the present structure of the economy) to reduce imports. These specified levels of imports are required to realise the planned incomes and consumption levels. Therefore, either savings have to fall below their planned levels or investment has to increase above planned level. However, there is no point in increasing investment above the planned levels since those are the minimum levels required to generate planned levels of income and consumption. Furthermore, increasing investment is not quite possible as it requires deliveries in specific proportions from the capital goods producing sectors of Modern Industry, Mining and Construction and Services. Such deliveries would have been possible if there are excess supplies in these sectors. But in the model solution, only few sectors record excess supplies.[1] Therefore, the only way in which investment could be increased, expost, is an involuntary increase in stocks. However, this cannot happen in each year because it would lead the economy towards a depression. Therefore the most appropriate adjustment process would be an increase in consumption, that is, a reduction in planned savings. However, this is not automatic. Specific policy action needs to be taken to guarantee an appropriate increase in consumption. This clearly highlights the possibility of an inverse relationship between foreign capital inflows and domestic savings. If the trade gap is dominating then the foreign financial assistance which is to forthcoming to fill the gap would, to a certain extent, lead to a level of lower realised savings compared with potential levels.

Given these results, it appears that the generation of more domestic savings as a strategy of promoting economic growth is questionable under the present conditions. In the solution with no public overhead investments, the savings constraints is redundant in all years except one. With public overhead investment both gaps are identical.

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1. Excess supplies were recorded in Mining and Construction in the first year. Tea and Rubber in the second year, Other agriculture and services in the fourth year and services in the fifth year.

If the savings constraint is not binding, there is no reason to increase savings. When both gaps are identical, generation of more savings would relax the savings constraint, but the trade constraint is still there. Therefore, additional savings would not alleviate the bottlenecks completely. On the other hand, if more foreign financial assistance is received, it would relax not only the trade constraints but also the savings constraint. Therefore, it appears that what is important under the present condition is not the promotion of domestic savings, but the availability of more foreign financial assistance. This conclusion is further supported by the solution of the same model but without the savings constraints. The solution of this model gives exactly the same results as reported in Tables 6.2 and 6.3. Therefore, there are reasonable grounds to conclude that the economic development in Sri Lanka is not constrained by the lack of domestic savings to finance investment requirements. On an optimal path of development, the development process would itself generate sufficient savings. Therefore, the principal restriction to economic development is the availability of foreign exchange.

However, the above argument does not necessarily mean that additional savings are not useful at all, even though it would not enable the economy to finance more investments. Additional savings may come through reducing the consumption of imported goods and thereby releasing some foreign exchange. Under such conditions additional savings would be useful in promoting economic growth as it would relax the foreign exchange constraints. However the important point is that this usefulness comes through only to the extent it releases foreign exchange.

A basic assumption behind the usual 'open loop' models is that, given the maximum feasible level of consumptions, savings requirements can be realised through the use of fiscal measures. Now by removing the savings constraints, we have converted our model into an open loop model. However, this means that investment could be increased without the limitations imposed by financial requirements. It does not take into account the fact that an increase in savings represents a reduction in demand for consumption.

As savings and consumption are strictly related to disposable income, any attempt to increase savings through the use of fiscal measures should be incorporated into the model and an optimal plan should be devised subject to the new conditions. For example, savings could be increased by increasing the rate of tax on the rich and/or reducing the rate of subsidy on the poor. Within the framework of our model, these changes cannot be introduced after the model is optimized. These new tax rates should be specified and the model should be re-optimized without removing the savings constraints.

6.4 Availability of Domestic Savings Increased by Removing Income Subsidy on the Poor

The above argument as to the usefulness of additional savings in releasing foreign exchange to promote economic growth is validated in an experiment which uses a fiscal measure to increase the availability of domestic savings. In this experiment the rate of income subsidy on the poor is reduced from 3.59% to zero percent, without introducing any other changes into the model. This increases the total availability of savings simply because it increases the savings by the government. According to this experiment, additional savings are useful because, it enables the model

either (i) to incorporate 57.44% of public overhead investments compared with 37.18% incorporated in the reference solution.

or (ii) to generate a higher level of discounted sum of GDP within the planning period without incorporating any public overhead investments.

Macro economic aggregates of the model solution with no income subsidy to the poor and no public overhead investments are shown in Table 6.4. These results can be compared with the results already reported in Table 6.3.

TABLE 6.4 MACRO ECONOMIC AGGREGATES OF THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT AND NO INCOME SUBSIDY ON THE POOR HOUSEHOLDS

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Products	16446	17421	18571	21340	22117
Plus Net Indirect Tax	2167	2364	2713	2742	2994
Gross Domestic Product at Market Prices	18613	19785	21284	24082	25111
Private Consumption					
Poor Households	7061	7471	8124	9471	9724
Rich Households	5110	5426	5770	6554	6870
Aggregate Private Consumption at Producer Prices	12171	12897	13894	16025	16594
Plus Net Indirect Tax	167	177	190	219	227
Aggregate Private Consumption at Market Prices	12338	13074	14084	16244	16821
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	3721	4022	4369	4857	5150
Ratio of Savings to GDP at Market Prices (%)	19.99	20.33	20.53	20.17	20.51
Aggregate Investment	3091	3722	4792	4046	4854
Plus Indirect Tax	417	502	647	546	655
Aggregate Investment at Market Prices	3508	4224	5439	4592	5509
Ratio of Investment to GDP at Market Prices (%)	18.85	21.35	25.55	19.07	21.94
Savings Gap	-213	202	1070	-265	359
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f.)	4399	4689	5015	5386	5803
Trade Gap	1070	1070	1068	1070	1070

As expected, the removal of the income subsidy on the poor results in increased levels of savings as well as savings ratios. Compared with the range of savings ratios from 18.38% to 19.12% in the solution with an income subsidy, the present solution represents a range of savings ratios from 19.99% to 20.53%, dropping the discounted sum of consumption (at producer prices) by 0.83%. However, the important point is that this increased availability of domestic resources for investment does not result in an increased level of overall investments. In fact, the discounted sum of investments at Rs. 16790 mn represents a 0.39% decline. Yet, the present solution represents a discounted sum of GDP of Rs. 78770 mn which is 1.38% higher. Therefore, increased savings results in a higher level of performance expressed in terms of the discounted sum of GDP.

This improvement in the discounted sum of GDP is largely due to the fact that the reduced level of demand for consumption makes it possible to release some foreign exchange, which was formerly used to finance competitive imports, and can now be used to finance non-competitive imports required to increase the output of those sectors which has idle capacities. Sectoral output levels in the first two years, in the present solution are exactly the same for all sectors except Mining and Construction and Services compared with the solution which incorporates an income subsidy. Therefore, given the same levels of outputs, a reduced level of demand for consumption means that a lower level of competitive imports is required to meet demand requirements. For the same reason, now the demand requirements in

Light Manufacturing can be met with a lower level of capacity in the third year, in which competitive imports of Light Manufacturing goods become zero. Therefore, the demand for investment is also lower in the first two years. As a result, competitive imports in the first two years are lower by Rs 2 mn and 8 mn respectively. This foreign exchange which is released from competitive imports is substantial enough to increase the output of Mining and Construction by 13.02% and 35.75%, and Services by 0.47% and 2.65% in each of the first two years respectively. As already seen in Table 5.10, with the income subsidy, Services had idle capacities in the first two years while Mining and Construction had idle capacities throughout the planning period. Thus as a result of this increased level of output in the early years, the discounted sum of output of Mining and Construction increases by 12.10% while that of Services increases by 0.38%. Also, Other Agriculture records a 1.19% increase in the discounted sum of output, generating excess capacities in the last two years while the discounted sum of output of the Light Manufacturing drops by 1.0%. Changes in the output levels in other sectors are marginal. Therefore, increased savings do not enable the model to finance more investments. Yet an improvement in the discounted sum of GDP is obtained due to the fact that the reduced level of consumption makes it possible to release some foreign exchange to be used in increasing the levels of output in those sectors which formally had idle capacities.

In the present solution, trade gap is dominant in all the years except the third. In the third year, trade gap is smaller by Rs. 2 mn. Even though there are idel canacities in the third year in Mining and

Construction, this foreign exchange could not be used in increasing domestic output, as it requires indirect inputs from sectors which are operating at full capacity and which are not importable. The present solution represents large amounts of excess savings. In the first and fourth years, in particular, available savings are more than sufficient to finance investment. Given the fact that the trade gap is dominant and as reasoned earlier[1] if, it is assumed that an expost increase in consumption would be made, then the ratio of realised savings to GDP in the present solution would be higher only in the third and fourth year, while in the remaining years it is lower. At the end of the planning period, the discounted sum of realised savings, in fact, would be 0.51% lower compared to the solution with income subsidy. This suggests that an attempt to increase planned savings may well end up without changing the overall level of realised savings. However, when public overhead investments are incorporated this is not true, because in that solution the two gaps are equal and hence planned savings equal realised savings. Moreover overall investment is higher, but when the public overhead investments are subtracted, there is no substantial change in the overall level of endogenous investments which generate productive capacities within the planning period.

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1. See pages 188-189.

6.3.5 Sensitivity of the Results for Changes in the Savings Ratios

So far, we have examined the situations corresponding to:

(i) the observed savings ratios of the poor and the rich households and other institutions in 1970, and

(ii) an increased availability of savings through fiscal measures.

Now it remains to examine the sensitivity of the above results, if the savings ratios were lower than what were observed in 1970. In particular, it should be noted that the aggregate savings ratios implicit in the model solutions are higher than the savings ratio (17%) observed in 1970 data base. This simply suggests that given the savings ratios of the poor, the rich and other institutions, it is possible to increase aggregate savings ratio , on an optimal path of development. Yet, one may suspect the reliability of the savings ratios of the poor, the rich and other institutions, specified in the model application as there seem to have been a downward trend in savings in recent years. For example, according to the estimates of the Central Bank, the aggregate savings ratio declined to 13.3% in 1979 from 15.0% in 1978. However this drop may well be due to an under estimation of savings.

The reason why savings may have been underestimated is as follows. After the liberalization of imports in 1977, there was a substantial amount of imports entering the economy. Therefore, it is quite possible for a large amount of stocks to have accumulated which were not accounted for in the official estimates of total investments. Hence, since savings are estimated indirectly by adjusting total investments for net foreign financial inflows, this would usually lead to an under-estimate of savings. Therefore, the savings ratios specified in the model application are likely to be reasonably realistic. Yet, it is still of some interest to see whether the above conclusions could be maintained at a lower ratios of aggregate savings. This is experimented by reducing the average saving ratio of the poor.

In the present set of experiments, the average (marginal) propensity to save out of disposable incomes by the poor households was reduced, thereby proportionately increasing the consumption ratios for all the sectors. Therefore the reduction of savings by the poor would not only reduce the amount of available domestic resources but would also impose a higher level of consumption demand for sectoral outputs. The model solution has to meet the targets with a lower level of available domestic resources while satisfying higher level of consumption demand. Therefore, it is hardly surprising that an infeasible solution resulted when the savings ratio of the poor households was reduced to zero. In the next step, the savings ratio of the poor households was reduced from 7.99% to 4.00% (that is, approximately halved) and an optimal feasible solution was found without incorporating any public overhead investments. In fact, only a 12.17% of the target level of public overhead investments could be incorporated without losing the feasibility of a solution. This should be compared with the 37.18% of the target level of public overhead investments we incorporated in the reference solution.

The implications of the reduced savings can further be analysed by looking at the macro economic aggregates of the model solution with no public overhead investment and reduced savings (4%) by poor households. These results are reported in Table 6.5 and can be compared with Table 6.3 where macro economic aggregate of the model solution with no public overhead investment and the savings ratio of the poor households was fixed at 1970 ratio of 7.99%.

TABLE 6.5 MACRO ECONOMIC AGGREGATES OF THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT AND REDUCED RATIO OF SAVINGS BY THE POOR HOUSEHOLDS

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	15626	16640	18664	20527	21490
Plus Net Indirect Tax	2168	2310	2585	2726	2878
Gross Domestic Product at Market Prices	17794	18950	21249	23253	24368
Private Consumption					
Poor Households	7278	7730	8859	9726	10079
Rich Households	4903	5234	5800	6386	6740
Aggregate Private Consumption at Producer Prices	12181	12964	14659	16112	16819
Plus Net Indirect Tax	167	177	201	221	230
Aggregate Private Consumption at Market Prices	12348	13141	14860	16333	17049
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	2892	3120	3558	3939	4179
Ratio of Savings to GDP at Market Prices (%)	16.25	16.47	16.74	16.94	17.15
Aggregate Investment	3491	3692	4078	3956	4365
Plus Net Indirect Tax	471	498	550	534	589
Aggregate Investment at Market Prices	3962	4190	4628	4490	4954
Ratio of Investment to GDP at Market Prices (%)	22.27	22.11	21.78	19.31	20.33
Savings Gap	1070	1070	1070	551	775
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f.)	4399	4689	5017	5386	5803
Trade Gap	1070	1070	1070	1070	1070

Reduction of the savings ratio of the poor households by 3.99 percentage points, resulted in a decline of overall savings ratio by approximately two percentage points. Accordingly discounted sum of investments (at producer prices) dropped by 4.06%. Thus the discounted sum of GDP (at producer prices) dropped by 1.84%. Despite the increase in the consumption ratio by the poor households, the overall level of consumption could not be increased significantly, as the lower level of domestic resources forced the economy to operate at a lower level of activity. The discounted sum of consumption of Rs. 59674 mn (at producer prices) is only 0.73% higher than what would have been obtained if there was no reduction in the savings ratio. With reduction in savings ratio by the poor households the model tries to generate as much savings as possible (in those years when lack of savings is critical) by adjusting the composition of sectoral outputs and incomes. This is indicated by the discounted sum of disposable income of the rich households being reduced by only 1.30% compared to 2.11% decline for the poor households. Thus, if the aggregate savings ratio is higher than 1970 level, additional savings do not enable the economy to finance more endogenous investment but if it is lower, then the savings become a problem and the economy is forced to reduce the overall level of endogenous investment to operate at a lower level of activity. If the savings ratio is lower than 1970 level then additional savings would enable the economy either to increase the overall level of endogeneous investment and to operate at a higher level of performance within the planning period or to incorporate some more public overhead investments.

If the savings ratio of the poor households was not reduced the two gaps are identical only in one year. With this reduction in the savings ratio, the two gaps are identical in all the first three years while the trade gap is dominating in the remaining two years. Following the usual logic one might argue that even at this lower level of savings, additional savings would not alleviate the bottlenecks completely as the economy is constrained by both the savings and foreign exchange constraints. However, this is not necessarily true. If the savings ratios were below the 1970 levels, the additional savings would relax the model constraints, allowing it to concentrate more on the incomes of the poor and thereby higher level of GDP. Additional savings mean a reduced level of demand for consumption, which would in turn enable the economy to increase exogenous investments. Thus an equality between the two gaps do not necessarily mean that additional savings are unimportant, especially if the model has the flexibility to adjust the sectoral composition of output to yield a higher value to the maximand. However, at ratios of savings which are higher than 1970 level, that flexibility disappears and additional savings would not enable the economy to increase the overall level of endogenous investments.

6.6 Sensitivity of the results to changes in the availability of Foreign Financial Assistance

So far, in all the solutions, available amount of foreign financial assistance was specified at Rs. 1070 mn a year. The present section examines the implications for different levels of foreign financial assistance. We mainly attempt to answer the following questions.

(i) What are the implications, if foreign financial assistance are lower than the reference value of Rs. 1070 mn a year and to what extent would it be possible to reduce the level of foreign financial assistance without loosing the feasibility of a solution?

(ii) What are the implications if foreign financial assistance are higher than the reference value?

As it was pointed out earlier, our reference solution was obtained at the maximum possible level of public overhead investment. This solution is highly sensitive and becomes infeasible, if foreign financial assistance is lower than Rs. 1070 mn a year, even with only 37.18% of public overhead investment . This factor alone is quite sufficient to highlight the importance of foreign financial assistance in developing the Sri Lankan economy.

However, if no public overhead investments are incorporated, the foreign financial assistance can be reduced by 47.81% a year while realising the other targets of the public investment programme. Macro economic aggregates of this solution which incorporates the minimum level of foreign financial assistance (i.e. approximately Rs 558 mn a year) to realise the plan targets other than public overhead investment are reported in Table 6.6.

TABLE 6.6 MACRO ECONOMIC AGGREGATES OF THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT WHEN EXPECTED NET FOREIGN FINANCIAL INFLOWS ARE REDUCED BY 47.81% PER YEAR.

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	15379	16469	18649	19870	20857
Plus Net Indirect Tax	2105	2261	2577	2770	2935
Gross Domestic Product at Market Prices	17484	18730	21226	22640	23792
Private Consumption					
Poor Households	6880	7344	8491	8998	9282
Rich Households	4823	5175	5785	6180	6558
Aggregate Private Consumption at Producer Prices	11703	12519	14276	15178	15840
Plus Net Indirect Tax	160	171	195	208	217
Aggregate Private Consumption at Market Prices	11863	12690	14471	15386	16057
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	3067	3351	3924	4273	4595
Ratio of Savings to GDP at Market Prices (%)	17.54	17.89	18.49	18.87	19.31
Aggregate Investment	3194	3444	3949	4256	4540
Plus Net Indirect Tax	431	465	533	575	613
Aggregate Investment at Market Prices	3625	3909	4482	4831	5153
Ratio of investment to GDP at Market Prices (%)	20.73	20.87	21.12	21.34	21.66
Savings Gap	558	558	558	558	558
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f)	3887	4177	4505	4874	5291
Trade Gap	558	558	558	558	558

As one might expect, this solution represents a lower level of performance compared with the solution with the reference value of foreign financial assistance and no public overhead investments. The discounted sum of consumption at Rs. 57105 mn (at producer prices) represents a 3.61% reduction while that of GDP (at producer prices) at Rs. 74937 represents a 3.56% decline. The discounted sum of investment (at producer prices) is 5.74% lower, while the ratio of investment is lower in each year except in the first year. Obviously the lower level as well as the lower ratio of investment is largely due to the lower availability of foreign financial assistance as there are not substantial differences in the savings ratios. (These differences are less than one percentage point). The two gaps are identical throughout the planning period, signifying the restraints imposed by the lower availability of foreign financial assistance both in financing investment and import requirements.

Further experiments were undertaken in the model with no public overhead investments by increasing the availability of foreign financial assistance over the reference value of Rs. 1070mn. For example, the macro economic aggregates of the model solution when foreign financial assistance is increased by Rs. 250 mn per year (i.e. it is fixed at Rs. 1320 mn per year) are reported in Table 6.7.

TABLE 6.7 MACRO ECONOMIC AGGREGATES OF THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT WHEN EXPECTED NET FOREIGN FINANCIAL INFLOWS ARE INCREASED BY Rs. 250 MN. PER YEAR

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	16569	16883	18749	22253	21959
Plus Net Indirect Tax	2191	2411	2753	2789	3076
Gross Domestic Product at Market Prices	18760	19294	21502	25042	25035
Private Consumption					
Poor Households	7361	7518	8481	10316	9938
Rich Households	5155	5287	5832	6777	6841
Aggregate Private Consumption at Producer Prices	12512	12805	14313	17093	16779
Plus Net Indirect Tax	171	175	196	234	230
Aggregate Private Consumption at Market Prices	12683	12980	14509	17327	17009
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	3523	3625	4162	4734	4886
Ratio of Savings to GDP at Market Prices (%)	18.78	18.79	19.36	18.90	19.52
Aggregate Investment	3181	4338	4830	4027	5350
Plus Net Indirect Tax	429	586	652	544	722
Aggregate Investment at Market Prices	3610	4924	5482	4571	6072
Ratio of Investment to GDP at Market Prices (%)	19.24	25.52	25.49	18.25	24.25
Savings Gap	87	1299	1320	-163	1186
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f.)	4649	4939	5267	5636	6053
Trade Gap	1320	1320	1320	1320	1320

With additional foreign financial assistance, more investment and imports could be financed. Compared with the solution with no public overhead investment and reference value of foreign financial assistance, an increased availability of foreign financial assistance results in a 5.58% increase in the discounted sum of investments (at producer prices). Accordingly, the discounted sum of GDP and consumption, (both at producer prices) record improvements of 1.83% and 1.75% respectively. This higher level of income generates a higher level of domestic savings as well even though the overall savings ratios are only marginally higher. The two gaps are identical only in the third year, while in all the other years the trade gap is dominating. Foreign financial assistance is important in financing the savings gap, but the dominating trade grap signifies the fact that it is more important in financing import requirements.

Given the results of the above experiments,we can examine how productive foreign financial assistance could be. This could be done either by examining the induced change in the value of the objective function or in the discounted sum of GDP at different levels of foreign financial assistance. The reference value of foreign financial assistance of Rs. 1070 mn a year represents a discounted sum of foreign financial assistance of Rs. 4462 mn while that of Rs. 558 mn a year represents a discounted sum of foreign financial assistance of Rs. 2327 mn throughout the planning period. At these two different levels of foreign financial assistance, the model solutions gave us discounted sum of GDP (at producer prices) of Rs. 77707 and Rs. 74937 mn respectively. Therefore, by increasing the discounted sum of foreign financial assistance by Rs. 2135 mn, discounted sum of GDP can be increased by Rs. 2770 mn. Therefore, at this level, productivity of foreign financial assistance is 1.2974 (i.e. 2770/2135). Similarly a further increase of foreign financial assistance by Rs. 250 mn a year represents an increase of Rs. 1042 mn in discounted sum of foreign financial assistance. This increase yielded an increase of Rs. 1422 mn in the discounted sum of GDP. Therefore at this level, productivity of foreign financial assistance is 1.3647. A further increase of discounted sum of foreign financial assistance by Rs. 1042 mn (i.e. additional Rs. 250 mn a year) would increase discounted sum of GDP by Rs. 1383 mn representing a productivity of 1.3273. The important point that should be noted is that this indicator of productivity is greater than unity. This means that every unit increase in the discounted sum of foreign financial assistance can be transformed into more than one unit of discounted sum of GDP. In this sense, foreign financial assistance are productive and Sri Lankan economy has the potential for making better use of foreign financial assistance.[1)]

As could be observed in the above productivity figures, there is a tendency in the productivity of foreign financial assistance to diminish after an initial increase. This could be further examined by looking

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1. In terms of the discounted sum of consumption, productivity figures become relatively lower. However, as we mentioned in the specification of the objective function, not only the consumption but also the savings should be arguments in the objective function. Therefore proper indicator of productivity should be defined in terms of the discounted sum of GDP.

at the changes in the value of the objective function at different levels of foreign financial assistance reported in Table 6.8.

TABLE 6.8

VALUE OF THE OBJECTIVE FUNCTION AT DIFFERENT LEVELS OF FOREIGN FINANCIAL ASSISTANCE

Foreign Financial Assistance, Rs. mn. per year	Value of the objective function, ln.	change in the value of the objective function, ln.
1070	29.98722	
1170	30.01634	0.02912
1270	30.04514	0.02880
1370	30.07377	0.02863
1470	30.09935	0.02558
1570	30.12062	0.02127
1670	30.13827	0.01765
1770	30.15375	0.01548
1870	30.16922	0.01547
1970	30.18171	0.01249
2070	30.19306	0.01135

As it could be seen, the change in the value of the objective function diminishes as the level of foreign financial assistance increases. This diminishing trend should be attributed to the following two reasons.

(1) The objective function is defined in terms of the utilities of the poor and rich households. This function reflects the property of diminishing marginal utility.

(2) Within the range of foreign financial assistance of Rs. 1170 p.a. to Rs. 2070 mn, in which the results are examined, labour becomes a binding constraint in the fourth year. In a sense, the availability of labour reflects the absorbtive capacity of the economy. There is a loss in efficiency in using foreign financial assistance, when labour constraint becomes binding in certain years. Usually an economy cannot absorb any amount of foreign financial assistance.

6.7 Exports of Other Agriculture increased by Rs. 250 mn in each year at Market Prices

This experiment was undertaken to examine the sensitivity of the model solution to an increased availability of foreign exchange through an increase in exports. This increase was maintained at Rs. 250 mn p.a. mainly to compare the results with our previous experiment reported in Table 6.23 where we experimented with an increased availability of foreign exchange by the same amount through foreign financial assistance. An increase in the exports of Other Agriculture by Rs. 250 mn p.a. at market prices represents increases of the same by Rs. 211 mn at producer prices plus exports of Services of Rs. 27 mn and export duty by Rs. 12 mn each year. Therefore, this imposes an additional demand on Other Agriculture and Services, and increases the availability of savings by Rs. 12 mn through this increase in the government revenue.

The summary results of this experiment in the model with no public overhead investment are reported in Table 6.9. It should be noted that with this increased availability of foreign exchange, the maximum amount of public overhead investments that could be incorporated becomes 38.74% of the target levels in each year, and compared with the reference solution, this represents an improvement of only 1.56 percentage points.

TABLE 6.9 MACRO ECONOMIC AGGREGATES OF THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT WHEN EXPORTS OF OTHER AGRICULTURE INCREASED BY RS. 250 MN P.A. AT MARKET PRICES

(Rs. mn at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	16253	16746	19121	21324	21957
Plus Net Indirect Tax	2183	2373	2692	2685	3020
Gross Domestic Product at Market Prices	18436	19119	21813	24009	24977
Private Consumption					
Poor Households	7233	7461	8723	9749	9981
Rich Households	5067	5252	5915	6585	6834
Aggregate Private Consumption at Producer Prices	12300	12713	14638	16334	16815
Plus Net Indirect Tax	168	174	200	224	230
Aggregate Private Consumption at Market Prices	12468	12887	14838	16558	17045
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	3414	3543	4144	4470	4792
Ratio of savings to GDP at Market Prices (%)	18.52	18.53	19.00	18.62	19.19
Aggregate Investment	3205	4044	4594	3770	4991
Plus Net Indirect Tax	433	546	620	509	674
Aggregate Investment at Market Prices	3638	4590	5214	4279	5665
Ratio of Investment to GDP at Market Prices (%)	19.73	24.01	23.90	17.82	22.68
Savings Gap	224	1047	1070	-191	873
Aggregate Exports (f.o.b)	3579	3869	4197	4566	4983
Aggregate Imports (c.i.f.)	4649	4939	5267	5636	6053
Trade Gap	1070	1070	1070	1070	1070

The results reported in Table 6.9 can be compared with Table 6.3 which shows the summary results of the model solution with the reference values of exports and no public overhead investment . Increased availability of foreign exchange through increased exports, results in only 0.76% increase in the discounted sum of GDP and 0.79% increase in the discounted sum of consumption. These increases are achieved through 0.38% increase in the discounted sum of investments. The two gaps are identical only in the third year and the trade gap dominates the savings gap in all the other years. These results should be compared with the improved performance we obtained by increasing the foreign financial assistance by the same amount. Comparative results are shown in Table 6.10.

TABLE 6.10

CHANGES IN THE KEY MACRO ECONOMIC AGGREGATES WHEN THE AVAILABILITY OF FOREIGN EXCHANGE IS INCREASED BY RS. 250 MN. PER YEAR

	Discounted sum of		
	GDP %	Consumption %	Investment %
Availability of Foreign Exchange is increased by increasing:			
(1) Exports	0.76	0.79	0.38
(2) Exports without incorporating savings constraint	1.11	1.18	0.78
(3) Foreign Financial Assistance	1.83	1.75	5.58

It is interesting to examine the reasons why an increase in the availability of foreign exchange by the same amount, but through two different routes generates different results; particularly why the increase in foreign financial assistance enables the economy to achieve substantially better performances compared to an increase in exports.

The first obvious reason is the savings constraint which is binding in the third year. An increase in the availability of foreign exchange through foreign financial assistance directly supplements the availability of domestic savings by exactly the same amount. But this is not the case when foreign exchange occurs through export earnings, Here, the additional savings comes only indirectly as a portion of the additional incomes and is specified by the savings ratios of the institutions and rate of export duty. In other words, additional foreign financial assistance alleviates both the foreign exchange and savings constraints directly by the same amount while the additional exports relax savings constraints only in an indirect way.

The extent to which the differences in the performance of additional foreign exchange by the two different routes are explained by savings constraints can be examined by looking at the model solution with increased exports but without incorporating savings constraints. This solution generates a discounted sum of GDP of Rs. 78570 mn which is 1.11% higher than that in the solution with reference value of exports.

Similarly it generates discounted sum of consumption of Rs. 59945 mn which is 1.18% higher and discounted sum of investment of Rs. 16986 mn which is 0.78% higher. Obviously this is a better performance than would be obtained in the solution which incorporates a savings constraint. Yet, these improvements are relatively low compared with those obtained through additional foreign financial assistance. Therefore, the differences in the performance of additional foreign exchange through two different routes are explained only partially by the lack of resources to finance investment .

The main reason why the model solution with additional foreign exchange through additional foreign financial assistance performs better is that the optimization procedure has the complete freedom to utilise the available foreign exchange through this route; that is, the optimization procedure can itself decide the sectors which should be developed. In contrast with this, the increased exports have to come through developing specific sectors and in the present case this is mainly the Other Agriculture sector and marginally the Services sector. Therefore, the freedom to use the additional foreign exchange is limited if it is forthcoming through additional exports. This point can be further highlighted by looking at the discounted sum of outputs in the relevant solution. These are reported in Table 6.11.

TABLE 6.11

DISCOUNTED SUM OF OUTPUTS IN THE SOLUTIONS WITH AN INCREASED AVAILABILITY OF FOREIGN EXCHANGE THROUGH TWO DIFFERENT ROUTES.

	Discounted sum of output in the solution with				
	(1) Reference value of exports	(2) Increased exports	change over(1) %	Inreased foreign financ. assist.	change over(1) %
1. Tea & Rubber	5215	5217	0.04	5224	0.17
2. Other agriculture	25864	26398	2.06	26372	1.96
3. Light Manufacturing	23787	23015	-3.24	23856	0.29
4. Modern Industry	11984	11897	-0.73	11919	-0.54
5. Mining & Construction	10905	10881	-0.22	12045	10.45
6. Services	33712	34135	1.25	34153	1.31

As it could be seen, with increased exports, discounted sum of output is increased only in Other Agriculture and Services, with a negligible increase in Tea & Rubber. These increases have to be achieved through a substantial reduction in the output of Light Manufacturing as well. This is mainly due to the fact that the model has to meet the exogenously specified additional demands for exports and therefore capacities have to be built up in these specific sectors. In contrast, when theadditional foreign exchange is available through foreign financial assistance the model has the freedom to use the idle capacities available in Mining and Construction, in addition to developing Other Agriculture and Services; and therefore it has the flexibility to make a greater contribution to the overall income and consumption.

6.8 Sensitivity of the Results to changes in Non Competitive Import Coefficients

For all the alternative solutions reported so far, non competitive import coefficients were fixed at the ratios estimated for 1979. As it could be seen in Table 4.8 these coefficients are relatively low compared with those estimated for 1970. This might well have been due to the past import substitution programmes. However, it is still worth examining the sensitivity of the results for changes in the non competitive import coefficients. For this purpose some experiments have been undertaken with the non competitive import coefficients estimated for 1970.

The reference solution with 37.18% public overhead investment become infeasible with the non competitive import coefficients estimated for 1970. However, now an optimal feasible solution can be obtained with 36.05% of the target level of public overhead investment . This is only a reduction of 1.13 percentage points. In fact as a whole, the introduction of 1970 non competitive import coefficients does not seem to substantially change the performance of the simulated economy we have already examined with 1979 non competitive import coefficients. Macro economic aggregates of the model solution with 1970 non competitive import coefficients and no public overhead investment are reported in Table 6.12.

TABLE 6.12 MACRO ECONOMIC AGGREGATES OF THE MODEL SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT WHEN NON-COMPETITIVE IMPORT COEFFICIENTS ARE FIXED AT ESTIMATES MADE FOR 1970

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	15969	16627	18603	21224	21723
Plus Net Indirect Tax	2151	2345	2660	2808	2974
Gross Domestic Product at Market Prices	18120	18972	21263	24032	24697
Private Consumption					
Poor Households	7124	7421	8461	9788	9827
Rich Households	4974	5204	5767	6501	6788
Aggregate Private Consumption at Producer Prices	12098	12625	14228	16289	16615
Plus Net Indirect Tax	166	173	195	223	227
Aggregate Private Consumption at Market Prices	12264	12798	14423	16512	16842
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate savings	3302	3485	4009	4539	4715
Ratio of Savings to GDP at Market Prices (%)	18.22	18.37	18.85	18.89	19.09
Aggregate Investment	3203	3996	4475	4157	4686
Plus Net Indirect Tax	432	539	604	561	633
Aggregate Investment at Market Prices	3635	4535	5079	4718	5319
Ratio of Investment to GDP at Market Prices (%)	20.06	23.90	23.89	19.63	21.54
Savings Gap	333	1050	1070	179	604
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f)	4399	4689	5017	5386	5803
Trade Gap	1070	1070	1070	1070	1070

Compared with the solution with 1979 non competitive import coefficients and no public overhead investment, this solution represents only a 0.60% and 0.55% reduction in the discounted sum of GDP and aggregate consumption. The discounted sum of investment is only 0.02% higher. As with 1979 import coefficients, the two gaps are equal only in the third year while in the remaining years the trade gap is dominating. Substantial differences appear only in the levels of competitive imports.

TABLE 6.13

COMPETITIVE IMPORTS

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
1. With 1970 non competitive Import coefficients	1726	1823	1934	1946	2345
2. With 1979 non competitive Import coefficients	2120	2244	2399	2573	2965
3. % reduction in (1) over (2)	18.58	18.76	19.38	24.37	20.91

As can be seen in Table 6.13, there is a substantial reduction in competitive imports in every year. This is to be expected, because with higher non competitive import coefficients, a lower amount of foreign exchange is available for competitive imports, given a fixed overall availability of foreign exchange. As a result, demands have to be satisfied by increasing the domestic output of those sectors which produce importable goods. This is revealed in Table 6.14 which compares discounted sum of outputsin the two solutions.

TABLE 6.14

DISCOUNTED SUM OF OUTPUTS IN THE SOLUTIONS WITH 1979 and 1970 NON COMPETITIVE IMPORT COEFFICIENTS

(Rs. mn. at 1970 prices)

	With the 1979 Coefficients	With the 1970 Coefficients	% change
1. Tea & Rubber	5215	5213	-0.04
2. Other Agriculture	25864	26005	0.54
3. Light Manufacturing	23787	23855	0.29
4. Modern Industry	11984	12118	1.12
5. Mining & Construction	10905	10664	-2.21
6. Services	33712	33055	-1.95

It can be observed that the discounted sum of output of all importable goods-producing sectors are higher with 1970 non competitive import coefficients. Among these sectors the percentage increase in the discounted sum of output of Modern Industry is relatively high. These higher levels of output in importable goods producing sectors are achieved at the expense of output in the remaining sectors. These differences in output levels explain the 0.60% and 0.55% reductions in the discounted sum of GDP and consumption.

6.9 Sensitivity of the Results for a Reduced Level of Targets for Terminal Capacities.

The flexibility of the model is highly constrained by the exogenously specified targets for terminal capacities. These targets as reported in Table 4.26 were specified using the projections made in Public Investment Programme. The present experiment examines the implications of lowering the targets below the reference values. The aim of this experiment is two-fold. First it would allow us to obtain an insight into possible trade-offs between economic development within the planning period and the development beyond the planning period as reflected by the targets for terminal capacities. Second a reduced level of targets would enable us to obtain a feasible solution with more public overhead investment , which would in turn provide us with more insight into the implications of public overhead investment on the economic development within the planning period. For this purpose, experiments were performed whereby targets for all sectors, except Tea & Rubber and Mining & Construction were reduced by 10%. Considering the excess capacities in Mining and Construction target levels of terminal capacities for this sector were reduced by 25%, while targets for Tea & Rubber were left unchanged.

The immediately observed result with the reduced target is that now a feasible optimal solution can be obtained with 100% of the public overhead investment planned, compared with only 37.18% we incorporated in the reference solution.. The full implications of this scenario can really only be ascertained by comparing the results of the zero and 100% public overhead investment for the reduced target model. Tables 6.15 and 6.16 show these results.

TABLE 6.15 MACRO ECONOMIC AGGREGATES OF THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT AND REDUCED TARGETS

(Rs. million at 1970 Prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	16192	16850	18722	21899	21899
Plus Net Indirect Tax	2164	2372	2660	2316	2550
Gross Domestic Product at Market Prices	18356	19222	21382	24215	24449
Private Consumption					
Poor Households	7209	7504	8531	10206	10183
Rich Households	5047	5278	5812	6704	6727
Aggregate Private consumption at Producer Prices	12256	12782	14343	16910	16910
Plus Net Indirect Tax	168	175	196	231	231
Aggregate Private Consumption at Market Prices	12424	12957	14539	17141	17141
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	3378	3576	4012	4093	4168
Ratio of Savings to GDP at Market Prices (%)	18.40	18.60	18.76	16.90	17.05
Aggregate Investment	3176	4075	4478	1163	2935
Plus Net Indirect Tax	429	550	604	157	396
Aggregate Investment at Market Prices	3605	4625	5082	1320	3331
Ratio of Investment to GDP at Market Prices (%)	19.64	24.06	23.77	5.45	13.62
Savings Gap	227	1049	1070	-2773	-837
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f.)	4399	4689	5017	5386	5803
Trade Gap	1070	1070	1070	1070	1070

TABLE 6.16 MACRO ECONOMIC AGGREGATES OF THE SOLUTION WITH 100% OF PUBLIC OVERHEAD INVESTMENT AND REDUCED TARGETS

(Rs. million at 1970 prices)

	1980	1981	1982	1983	1984
Gross Domestic Product	15904	16954	18116	18539	19451
Plus Net Indirect Tax	2238	2391	2512	2517	2646
Gross Domestic Product at Market Prices	18142	19345	20628	21056	22097
Private Consumption					
Poor Households	7087	7536	8123	8280	8603
Rich Households	4981	5317	5662	5823	6154
Aggregate Private Consumption at Producer Prices	12068	12853	13785	14103	14757
Plus Net Indirect Tax	165	176	189	193	202
Aggregate Private Consumption at Market Prices	12233	13029	13974	14296	14959
Public Expenditure (current)	2554	2689	2831	2981	3140
Aggregate Savings	3355	3627	3823	3779	3998
Ratio of Savings to GDP at Market Prices (%)	18.49	18.75	18.53	17.95	18.09
Aggregate Investment	3899	4138	4311	4272	4465
Plus Net Indirect Tax	526	559	582	577	603
Aggregate Investment at Market Prices	4425	4697	4893	4849	5068
Ratio of Investment to GDP at Market Prices (%)	24.39	24.28	23.72	23.03	22.93
Savings Gap	1070	1070	1070	1070	1070
Aggregate Exports (f.o.b)	3329	3619	3947	4316	4733
Aggregate Imports (c.i.f.)	4399	4689	5017	5386	5803
Trade Gap	1070	1070	1070	1070	1070

At first, results given in Table 6.15 are compared with result of the model solution with full targets and no public overhead investment , (see Table 6.3), to botain an insight into trade-offs between development within and beyond the planning period.

A reduction in the target does not seem to give rise to a substantial improvement in performance within the planning period, because the economy is so highly constrained by the availability of foreign exchange. The discounted sum of GDP and aggregate consumption increased by only 0.88% and 1.25% respectively. The most significant feature of the present solution is the substantial reduction in the overall level of investment . The discounted sum of investment of Rs. 13460 mn. represents a 20.14% reduction compared with that in the solution with full targets and no public overhead investment . Obviously a lower level of investment is required to attain the lower targets. However, as relatively lower level of investments are now required to attain the targets, one might have expected the model solution to generate more capacities within the planning period, so that more incomes and consumption could be enjoyed within the planning period. Yet, as reported earlier, the improvement in GDP and consumption is very small. This is due to the restrictive nature of other constraints. For example, the developments in the first two years are constrained by initial capacity levels and initial capital in process. The model has complete freedom to generate capacities only in the last three years; but that freedom is restrained by the availability of foreign exchange. A lower level of targets reduces the demand for output only of the investment goods supplying sectors. But, if incomes are increased, all the sectors have to meet a higher level of demand for consumption.

It is also noteworthy that even with the reduced targets, the two gaps are equal only in the third year, while the trade gap dominates in all remaining years. This is exactly the same situation as with the full targets. But the difference is that with the reduced targets, savings exceed investments substantially in the last two years, even though the aggregate savings ratios are relatively low. With the full targets, savings exceeded investment by Rs 19 mn. in the fourth year while in the fifth year, there was a savings gap of Rs. 784 mn. In contrast, with reduced targets savings exceed investments in both fourth and fifth years by Rs. 2773 mn. and Rs. 837 mn. respectively. It is of course a matter for the political authority to decide whether 1.25% increase in the discounted sum of consumption is significant. However, the domestic resources of these magnitudes which are going to be idle or converted back to consumption in the last two years must be taken into consideration when making a value judgement as to the appropriateness of reducing the targets.

Throughout this chapter the adverse effects of public overhead investment on theeconomic development within the planning period have been emphasized. However, the full impact of the public overhead investment could not be highlighted as we could not obtain a solution incorporating more than 37.18% of the public overhead investment and simultaneously maintain full targets. Now with the reduced targets, a feasible optimal solution can be obtained with all the public overhead investment planned and its full impact can be examined by comparing the results of the model solutions with reduced targets with and without public overhead investment . The summary results are reported in Tables 6.15 and 6.16.

The overall results of incorporating all public overhead investment would be a 6.24% reduction in the discounted sum of GDP and 6.94% reduction in the discounted sum of aggregate consumption. These reduced levels of performance are accompanied by a 29.89% increase in the discounted sum of investment . However, this increase is entirely due to the exogenously incorporated public overhead investments which do not contribute to the productive capacities within the planning period. In fact, despite this substantial increase in the discounted sum of total investment , the discounted sum of fixed endogenous investments which are instrumental in generating productive capacities within the planning period has actually dropped by 20.88%. This adverse performance within the planning period is wholly explained by the similar reasons to those advanced on page 187 .

CHAPTER 7.

Distributional Implications of the Model Solutions.

This chapter examines the distributional implications of the model solutions. This examination is facilitated by the very nature of our objective function which expresses the social welfare in terms of the weighted sum of the utilities of the poor and rich households.

7.1 Reference Solution.

The basic features of the reference solution pertaining to the distribution of incomes and utilities are summarised in Table 7.1. For this solution weights are assigned to the utilities of the poor and the rich households in the objective function which are proportional to the number of households in the group. (i.e. approximately 81% of the poor and 19% of the rich households.)

As can be seen, GDP[1)] grows at increasing rates until 1982. Having reached the peak growth rate of 11.80% in 1982, it then grows at a diminishing rate in the remaining years. The same pattern of growth can be seen in the disposable incomes of both the poor and the rich households, even though there are some differences in the actual growth rates. In the peak year of 1982, disposable incomes of the poor

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1. This Chapter refers only to the projection of GDP at Producer Prices.

TABLE 7.1.

INCOMES AND UTILITIES OF THE POOR AND THE RICH HOUSEHOLDS IN THE REFERENCE SOLUTION (at 1970 prices)

	1979 (Pre Plan Year).		1980	Growth rate %	1981	Growth rate %	1982	Growth rate %	1983	Growth rate %	1984	Growth rate %	Discounted Sum	
Total Disposable Income of Poor (Rs.mn)	7699	(48.21)	7626	-0.95 (48.50)	8137	6.70 (48.35)	9268	13.90 (49.26)	9906	6.88 (49.15)	10186	2.83 (48.33)	37082	(48.72)
Total Disposable Income of Rich	6248	(39.13)	6169	-1.26 (39.23)	6613	7.20 (39.30)	7315	10.61 (38.88)	7841	7.19 (38.90)	8293	5.76 (39.35)	29782	(39.13)
Utility of Poor (per household) ln	6.81037		6.80084	-0.14	6.86570	0.95	6.99584	1.89	7.06242	0.95	7.09029	0.39	28.97294	
Utility of Rich (per household) ln	7.96815		7.95542	-0.16	8.02492	0.87	8.12581	1.26	8.19525	0.85	8.25130	0.68	33.75931	
Gross Domestic Product at Producer Prices (Rs.mn)	15968		15724	-1.53	16828	7.02	18814	11.80	20154	7.12	21076	4.57	76108	

Income Shares in GDP are reported within the brackets.

grows at a relatively high rate compared with that of the rich hous...... Accordingly the income share of the poor households increases from the pre plan share of 48.21% to 49.26%, reducing the income share of the rich households from 39.13% to 39.89%. However, after 1982, disposable income of the poor households grows at a relatively low rate compared with that of the rich households. Therefore at the end of the planning period, in terms of the discounted sum of disposable incomes of the poor and the rich households, the income share of the poor and the rich households in the discounted sum of GDP, remains almost unchanged at the shares corresponding to the pre plan year (1979). The slight increase in the income share of the poor households is achieved only at a reduced income share of the Other institutions. The income share of the rich households remained unchanged at the pre plan level.

This result suggests that the disposable incomes of the poor and the rich households are strongly linked. The objective function has relatively large weight (0.81) on the utilities of the poor households and therefore one would expect the optimal growth process to favour the poor households and to increase their share of incomes. However, due to the inherent structure of the economy and intersectoral linkages, a production plan which aims at providing more incomes for the poor households would necessarily generate substantial amounts of income for the rich households as well. Examples of basic linkages which account for this specific behaviour of the solution are:

1. 'Other Agriculture' has the second largest income coefficient for the poor households. This same sector has the second largest income coefficient for the rich households.

2. The poor's propensity to consume the output of 'Services' is 0.2747. This represents the poor's second largest consumption item. This sector has the highest income coefficient for the rich.

3. The poor receives their incomes largely from 'Tea & Rubber' and 'Other Agriculture'. Production of outputs in these sectors requires indirect inputs and capital goods from 'Modern Industry'. 'Modern Industry' provides proportionately more income for the rich.

Therefore the basic feature of the solution is that the optimal plan provides incomes for both the poor and the rich, without changing their relative income shares significantly. Even in terms of the per household disposable income, there does not seem to be a substantial reduction in the disparity between the poor and the rich which prevailed in the pre plan year. In the pre plan year the disposable income of an average poor household was only 0.2932 of the disposable income of an average rich household. At the end of the planning period, the discounted sum of dispoable income received by an average poor household is still only 0.2963 of the discounted sum of disposable income received by an average rich household. Therefore, there is no perceptible difference. This same picture could be observed in utilities enjoyed by an average poor and rich household. By the end of the planning period, an average rich household would have enjoyed a discounted sum of utilities of ln 33.74697 which is 16.52% higher than the discounted sum of utilities enoyed by an average poor household. This difference is largely explained by the disparity in the pre-plan year. In the pre plan year, the utility enjoyed by an average rich household was 17% higher than that by an average poor household. Therefore now it is quite clear that the optimal plan would provide incomes and utilities for both the poor and the rich households, but it would not improve the relative position of the poor substantially.

This result is quite important as it suggests that given the initial conditions and terminal requirements (targets), the production structure can not be altered to yield a higher share of income for the poor. The validity of this conclusion can be further investigated by examining the sensitivity of this result for the changes in weights attached to the poor and the rich. Basically two alternative solutions are examined. i.e.

1. Rowlsian (Maximin) Solution.

   This solution is obtained by assigning weight of one on the poor and zero on the rich.

2. Utilitarian Solution.

This is obtained by assigning same weight to both the poor and the rich.

However, the Rawlsian and Utilitarian Solutions were both found to be exactly the same as the reference solution reported above. This rigid insensitivity of the result to the changes in the weights, strongly support our earlier conclusion that the production structure can not be altered to change the income shares in favour of the poor. The optimal development strategy generates incomes for the rich as well as the poor.

However, these results are still not quite conclusive. The insensitivity of the reference solution might have been due to other factors. In particular, it should be noted that the reference solution was obtained at the maximum possible level of public overhead investment and therefore any deviation from this solution may not be possible. It is important to note that, even though the model has a single objective function, there are two other objectives incorporated into the model through constraints; namely, the target level of public overhead investment and terminal capacities. In Tinbergen's terminology, these can be considered as 'Fixed' objectives while the objective function itself reflects the 'Flexible' objective of the utilities of the poor and the rich. In the maximization process, these fixed objectives receive first priority and it is similar to incorporating these arguments in the objective function with weights of infinity until the specified levels are reached. Therefore it may be the case that once the resources are allocated to achieve these fixed objectives, there might not be much flexibility left to improve the share of the poor. This possibility can be tested by examining the following solutions, each of which ought to allow a certain amount of flexibility:

1. Solution without any public overhead investment, ie. alternative reference solution.

2. Solution without any public overhead investment and reduced levels of targets for terminal capacity requirements.[1)]

7.2 Alternative reference solution.

The summary results pertaining to the incomes and utilities of the poor and the rich in the alternative reference solution are reported in Table 7.2. It should be noted that even without public overhead investment, the model still does not differentiate between Rawlsian and Utilitarian Solution. Therefore, the results reported in Table 7.2 correspond to both Rawlsian and Utilitarian solutions.

The present solution records increasing growth rates in GDP until 1983. Accordingly, the disposable incomes of both the poor and the rich grow at increasing rates until 1983. Both in 1982 and 1983, disposable income of the poor grows at a relatively higher rate to that of the rich, increasing the poor's income share up to 49.20%

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1. Targets are reduced by the same percentages as reported in Chapter 6 section 6.9. (See p.221.)

TABLE 7.2.

INCOMES AND UTILITIES OF THE POOR AND THE RICH HOUSEHOLDS IN THE ALTERNATIVE REFERENCE SOLUTION (at 1970 prices)

	1979 (Pre Plan Year)		1980	Growth rate %	1981	Growth rate %	1982	Growth rate %	1983	Growth rate %	1984	Growth rate %	Discounted Sum
Total Disposable Income of Poor (Rs.mn)	7699	(48.21)	7835	1.77 (48.39)	8109	3.50 (48.43)	9164	13.01 (49.20)	10694	16.70 (50.03)	10693	-0.01 (49.21)	38118(49.05)
Total Disposable Income of Rich (Rs. mn)	6248	(39.13)	6323	1.20 (39.05)	6574	3.97 (39.27)	7261	10.45 (38.98)	8217	13.17 (38.45)	8504	3.49 (39.13)	30282 (38.97)
Utility of Poor (per householde) ln	6.81037		6.82788	0.26	6.86225	0.50	6.98456	1.78	7.13896	2.21	7.13887	0.0	29.07820
Utility of Rich (per household) ln	7.96815		7.98008	0.15	8.01901	0.49	8.11840	1.24	8.24209	1.52	8.27642	0.42	33.82482
Gross Domestic Product at Producer Prices (Rs.mn)	15968		16192	1.40	16742	3.40	18627	11.26	21373	14.74	21731	1.67	77707

Income shares in GDP are reported within the brackets.

and 50.03% respectively. This represents 0.99 and 1.82 percentage point increases in the poor's income share in the respective years. The income share of the rich correspondly declines by 0.15 and 0.68 percentage points in these years. However, in the final year, the disposable income of the rich grows by 3.49% improving their share of income up to the share of the pre plan year, while the disposable income of the poor remains almost unchanged at the 1983 level. By the end of the planning period, in terms of the discounted sum of disposable incomes, the poor's share in discounted sum of GDP increased only by 0.84 percentage points while the share of the rich declined by 0.16 percentage points. The increase in the poor's share, though not substantial, is largely achieved by reducing the income share of the 'Other institutions'. Therefore, the main conclusion of the reference solution still remains. Even without the public overhead investment , the optimal growth process would generate incomes for both the poor and the rich without changing the income shares substantially.

The rigid insensitivity of the model solution for changes in the weights on the objective function simply re-confirms the earlier conclusion. Even if no weights were attached to the utility of the rich, the model generates income for the rich due to the linkages between the income generating activities of the poor and the rich. Income generating activities of the poor cannot be separated from the rich. Therefore, any attempt to improve the position of the poor, on an optimal path, by means of production planning, would end up generating more incomes for both the poor and the rich without affecting income shares substantially. Further, this insensitivity suggests that there are no differences which could be achieved by changing the decision making criterion from Utilitarian to Rawlsian.

Another important point which should be highlighted is the implication of public overhead investment on the distribution of incomes. We have seen in Chapter 6 (see section 6.3), that the introduction of public overhead investment reduces the discounted sum of GDP by 2.06%. What is important in the present context is that this reduction in the discounted sum of GDP is accompanied by a 2.72% decline in the discounted sum of the disposable income of the poor while that of the rich declines only by 1.65%. In absolute term, discounted sum of disposable income of the poor declines by Rs 1036 mn while that of the rich declines only by Rs 500 mn. Therefore, the poor households as a group bears a larger portion of the cost of public overhead investments, in terms of the potential increments in the disposable incomes that could have been achieved if no public overhead investments were incorporated. This picture changes a little if the loss in average household income of the poor and the rich were compared. In terms of the discounted sum of average household incomes, an average poor household loses Rs 525 while an average rich household loses Rs 1065 due to the introduction of public overhead investments. However, a loss of Rs 525 to a poor household cannot strictly be compared with a loss of Rs 1065 to a rich household, as the marginal utility of income is larger for a poor household compared to a rich household. In terms of the discounted sum of utilities of an average household, an average poor household loses ln 0.10526 units of utilities while an average rich household loses only ln 0.06551 units of utilities. Therefore, in terms of the potential increment of incomes and utilities that would have been enjoyed if no public overhead investments were incorporated, it is the poor who suffer most by the incorporation of public overhead investments.

7.3 Solution with Reduced Targets.

Basically the above points are reconfirmed by the solution with no public overhead investments and reduced targets. The summary results pertaining to the distribution of incomes and utilities in this solution are shown in Table 7.3. Even with reduced targets there are no differences between the Rawlsian and Utilitarian solutions. Therefore the results reported in Table 7.3 again correspond to both Rawlsian and Utilitarian solutions.

As we have pointed out in Chapter 6 (see p.224), a reduction in the targets does not seem to have induced the model to generate a substantial increase in the discounted sum of GDP. Compared to the solution with no public overhead investments, the present solution provides only 0.88% increase in the discounted sum of GDP. However, the important point in the present context is that both the poor and

TABLE 7.3

INCOMES AND UTILITIES OF THE POOR AND THE RICH HOUSEHOLDS IN THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT and REDUCED TARGETS.

(at 1970 prices)

	1979 (Pre Plan Year)		1980	Growth rate %	1981	Growth rate %	1982	Growth rate %	1983	Growth rate %	1984	Growth rate %	Discounted Sum	
Total Disposable Income of Poor (Rs.mn)	7699	(48.21)	7835	1.77 (48.39)	8156	4.10 (48.40)	9272	13.68 (49.52)	11092	19.63 (50.65)	11067	-0.22 (50.54)	38805	(49.50)
Total Disposable Income of Rich (Rs.mn)	6248	(39.13)	6323	1.20 (39.05)	6612	4.57 (39.24)	7282	10.13 (38.89)	8399	15.34 (38.35)	8428	0.34 (38.49)	30419	(38.80)
Utility of Poor (per household) ln	6.81037		6.82788	0.26	6.86803	0.59	6.99627	1.87	7.17550	2.56	7.17324	-0.03	29.14406	
Utility of Rich (per household) ln	7.96815		7.98008	0.15	8.02477	0.56	8.12129	1.20	8.26400	1.76	8.26745	0.04	33.84278	
Gross Domestic Product at producer prices (Rs.mn)	15968		16192	1.40	16850	4.06	18722	11.11	21899	16.97	21899	0.0	78393	

the rich benefit by this increase in the discounted sum of GDP. Discounted sum of disposable income of the poor and the rich increase by 1.80% and 0.45% respectively. Compared with the solution with no public overhead investments, the present solution increases the income share of the poor and reduces the income share of the rich, but these changes are marginal; that is, in terms of the discounted sum of disposable incomes, the income share of the poor increases by 0.45 percentage point while that of the rich declines by 0.17 percentage points. Compared with the pre plan shares, the poor's share of 49.50% represents an improvement of only 1.29 percentage point while the share of the rich declines only by 0.33 percentage point.

Comparing the reference solution with alternative reference solution, we pointed out the fact that a larger portion of the cost (in terms of the loss in incomes within the planning period) of public overhead investments is borne by the poor. Similarly, it can be shown that a larger portion of the cost of additional capacities for the growth in post-terminal period is also borne by the poor, by comparing the full and reduced target, no public investment solutions. Targets have been defined in terms of the capacity requirements of the post-terminal years. Therefore by moving from the solution with reduced targets to the full target solution, we provide more capacities for the growth in the post planning period. This provision of additional capacities for the growth in the post planning period is accompanied by a 0.88% reduction in the discounted sum of GDP - that could be obtained within the planning period.

This can be considered as a cost of providing additional capacity for the growth in the post planning period. The important point is that this cost is largely borne by the poor. By providing this additional capacity, the poor lose Rs 687 mn in discounted sum of disposable incomes (i.e. a 1.77% reduction) while the rich lose only Rs 137 mn (i.e. only a 0.45% reduction) in discounted sum of disposable incomes. In terms of the discounted sum of utilities of an average household, the poor lose ln 0.06586 units of utility while the rich lose only ln 0.01796 units of utility. Therefore, it is clear that the cost (in terms of the lost incomes and utilities) of providing additional capacities for the growth in post planning period is largely borne by the poor.

7.4 An overview of the Results so far.

All the solutions examined so far provide evidence for a similar set of conclusions. The following are particularly worth emphasising:

(i) The optimal development strategy is insensitive to the choice of decision criterion. i.e. there are no differences in outcome between the Utilitarian and Rawlsian solutions. Usually the analyst's task is to draw the utility feasibility frontier between Utilitarian and Rawlsian solutions. It is the task of the plitical authority to express the degree of equality desired and thereby select a solution on the frontier. However, in the Sri Lankan case, this task of the political authority seems to have become easier as there are no differences between Utilitarian and Rawlsian solutions.

(ii) Exogenously imposed public overhead investments and terminal capacity requirements carry a cost in terms of the loss in incomes and utilities within the planning period. A large proportion of this cost is borne by the poor.

(iii) On an optimal development path, economic growth would not worsen the position of the poor. Rather both the poor and the rich would benefit by growth. This result in a sense, is a counter evidence to the Kuznet's 'U' hypothesis which claims that the relative distribution of incomes first becomes more unequal in the course of economic development and only at the later stage becomes more equal. In general, Kuznets hypothesis may be correct historically, but there could be some individual economies which prove otherwise. The important point is that a planned economic development should not necessarily have to follow such a pattern of development.

In particular, the Sri Lankan case is quite special. Income distribution has already changed in favour of the poor with slower economic growth from 1963 to 1973. The Gini coefficient declined from 0.49 in 1963 to 0.41 in 1973 while GDP grew by an annual average rate of 4.14% during the same period. Growth occurred mainly in those sectors which provide most of the incomes for the poor. i.e. mainly in agriculture. By contrast, in 1978 the Gini coefficient rose to 1963 level of 0.49 with a more substantial growth of 8.2% in GDP. The main reason for the increased Gini coefficient in 1978 is the fact that even though the growth was spread across more sectors the Services sector grew relatively more than the other. On the other hand, the sector which has the highest income coefficient for the poor, i.e. Tea & Rubber, recorded a decline. Developments in the subsidiary food crops activities which are contained in the 'Other Agriculture' were not quite so impressive. The slower growth from 1963 to 1973 was not due to the change in income distribution in favour of the poor. During that period growth was generally handicapped by restrictions and controls which caused scarcities in the materials required to support growth. The increased Gini coefficient in 1978 was, to a certain extent, due to the neglect of agriculture (mainly subsidiary crops) and agriculture-based light manufacturing industries.

Past developments can not strictly be compared with an optimal development path. However, the important point is that if the economy follows an optimal development path, then the economic development on that path would not worsen the relative position of the poor, yet it would generate the maximum possible growth in total incomes.

(iv) Given the technologically determined income coefficients and production relationships, no resource allocation could be found on an optimal development path to give a production plan which represents a substantial improvement in the income share of the poor. In the otherwords, initial inequality in the utilities of the poor and the rich in the pre plan year is not significantly reduced by the end of the planning period. Throughout the planning period, per household disposable income of the rich is more than three times that of the poor. Given the present income and production coefficients, the above results suggest that production planning cannot be used as an instrument in changing the disparity in incomes and improving the relative position of the poor. Therefore the appropriate instruments should be the use of fiscal measures and a change in the production technology in such a way as to yield more incomes for the poor.

7.5 Solution with no taxes and subsidies on Households.

This provides a good point of departure for us to examine the implications of income transfer policies. In this respect it is useful to recall our specification of income relationships,

$$TYP(t) = (1-t_P)[V_P'X(t) + VG_P(t)]$$

$$TYR(t) = (1-t_R)[V_R'X(t) + VG_R(t)] \quad ,$$

where TYP and TYR are total disposable incomes of the poor and the rich while V_P' and V_R' are row vectors of income (value added) coefficients on the poor and the rich respectively. X is the vector of outputs and value added by government (VG) is exogenously specified and distributed between the poor (VG_P) and the rich (VG_R).

What is important in the present context is the role of t_P and t_R which specify tax rates on the poor and the rich incomes respectively. These tax rates can be used to transfer incomes between the poor and the rich. e.g. an increase in t_R and a corresponding reduction in t_P would represent a transfer of income from the rich to the poor. An important point that should be noted is that net income coefficient, i.e. $(1-t_P)V_P'$ and $(1-t_R)V_R'$ would be higher when an income subsidy is given and lower when an income tax is applied. Therefore an income subsidy for the poor and an income tax for the rich reflect in the model as if all the sectors are providing relatively more incomes for the poor and less for the rich. These higher incomes for the poor and less incomes for the rich affect the production structure as the consumption pattern of the poor is different from that of the rich. Thus the production structure can be affected by changing t_P and t_R .

For all the solutions discussed so far, values of t_P and t_R were set at -0.0359 and 0.1088 respectively. In the data base, these values represent composites of direct and indirect taxes and subsidies. In other words, according to the data base, the net effect of all taxes and subsidies on households had been a 3.59% subsidy on the poor incomes and 10.88% tax on the rich incomes. The production structure and income distribution in all the above solutions have been affected by these taxes and subsidies. Therefore it is quite interesting to see what would have happened if there were no subsidy to the poor and no tax on the rich. It would enable us to examine the benefits and disbenefits achieved by subsidising the poor by 3.59% and taxing the rich by 10.88%.

Summary results pertaining to the distribution of incomes and utilities in the solution with no taxes on the rich households and no subsidies on the poor households are presented in Table 7.4. It should be noted that this experiment was undertaken in the model with no public overhead investment.

As can be seen, this solution also confirms the earlier conclusions as to the inability of production planning to change the income shares substantially and insensitivity of the model solution to the changes of weights in the objective function. Income shares of the poor and the rich increase by only 0.60 and 0.07 percentage points respectively compared to the pre plan shares that would have prevailed if there were no taxes and subsidies on households in the pre plan year. These increases are only marginal and are accompanied with a reduced share of income for other institutions. Even with no taxes and subsidies on households there is no difference between Rawlsian and Utilitarian solutions.

More interesting information is revealed in Table 7.5 where the solution with income taxes and subsidies is compared with the solution without income taxes and subsidies on households.

TABLE 7.4.

INCOMES AND UTILITIES OF THE POOR AND THE RICH HOUSEHOLDS IN THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT and NO TAXES AND SUBSIDIES ON HOUSEHOLDS.

(at 1970 prices)

	1979 (Pre Plan Year)		1980	Growth rate %	1981	Growth rate %	1982	Growth rate %	1983	Growth rate %	1984	Growth rate %	Discounted Sum	
Total Disposable Income of Poor (Rs.mn)	7432	(46.54)	7454	0.30 (46.79)	7866	5.53 (46.68)	8804	11.92 (47.41)	9559	8.58 (47.69)	10093	5.59 (47.13)	35956	(47.14)
Total Disposable Income of Rich* (Rs.mn)	7010	(43.90)	7014	0.06 (44.03)	7446	6.16 (44.18)	8143	9.36 (43.85)	8765	7.64 (43.73)	9431	7.60 (44.04)	33540	(43.97)
Utility of Poor (per household)ln	6.77507		6.77803	0.04	6.83183	0.79	6.94448	1.65	7.02676	1.18	7.08112	0.77	28.84383	
Utility of Rich (per household)ln	8.08322		8.08379	0.01	8.14356	0.74	8.23304	1.10	8.30665	0.89	8.37989	0.88	34.25568	
Gross Domestic Product at Producer Prices (Rs.mn)	15968		15929	-0.24	16852	5.79	18568	10.18	20045	7.95	21414	6.83	76281	

Income shares in GDP are reported within the brackets.

TABLE 7.5.

Comparison of Results in the solutions with and without Income Taxes and Subsidies on Households.

	Without income taxes and subsidies	With income taxes and subsidies	% change
Discounted sum of:			
Disposable Income of Poor (Rs.mn)	35956	38118	6.01
Disposable Income of Rich (Rs. mn)	33540	30282	-9.71
Utility of Poor (per household, ln)	28.84383	29.07820	0.81
Utility of Rich (per household, ln)	34.25568	33.82482	-1.26
Gross Domestic Product (Rs.mn)	76281	77707	1.87
Income share of:			
Poor (per centage)	47.14	49.05	4.05
Rich (per centage)	43.97	38.97	-11.37

The overall effects of subsidising the poor's income by 3.59% and taxing the rich by 10.88% would be, on an optimal path, to increase the discounted sum of disposable income of the poor by 6.01% while reducing the discounted sum of disposable income of the rich by 9.71%. The income share of the poor would be increased by 4.05% while that of the rich would be reduced by 11.37%. The disparity in the utilities between the rich and the poor would be reduced from 18.76% to 16.32%. A more interesting fact is that these changes would be accompanied by a 1.87% increase in the discounted sum of GDP. Therefore, the redistributive role of taxes and subsidies would be effective in favour of the poor and not be in conflict with economic growth. In other words, the policy for improving the relative position of the poor would promote economic growth as well. The reasons behind this particular feature of the model solution lies in the differences in the production structure as revealed in Table 7.6.

These changes in the structure of output should be explained mainly by the changes in the overall demand for consumption of the sectoral outputs. With relatively higher disposable incomes for the poor and less for the rich (compared to the pre-tax position), Other Agriculture and Light Manufacturing have to meet a higher consumption demand while the demand for Modern Industry is reduced. As the Modern Industry has the highest non competitive import coefficient, a decline in the output of Modern Industry releases some foreign exchange which

TABLE 7.6.

Discounted Sum of Outputs in the Solutions with and without Income Taxes and Subsidies on Households.

	without income taxes and subsidies	with income taxes and subsidies	% change
1. Tea & Rubber	5243	5215	-0.53
2. Other Agriculture	24887	25864	3.93
3. Light Manufacturing	22664	23787	4.95
4. Modern Industry	12136	11984	-1.25
5. Mining & Construction	10111	10905	7.85
6. Services	33734	33712	-0.06

can be used to increase the output of Mining & Construction, since it has a recorded level of idle capacity. On the other hand, those sectors which record increases in output level tend to make a substantial contribution to the GDP. In particular, Other Agriculture has the highest value added coefficient. Even the value added coefficient of Mining & Construction is higher than that of Modern Industry. Therefore these changes in the structure of the output resulted in a higher level of

GDP as well. However, this result should be interpreted with due caution as it is based on an assumption of fixed consumption coefficients. If the consumption ratios of the poor change in such a way that incremental demand for the output of Modern Industry is high relative to that of Other Agriculture and Light Manufacturing, an imposition of taxes on the rich and subsidies on the poor may not be accompanied by an increase of the discounted sum of GDP. Therefore, within the limitations of a fixed coefficient model, it can be concluded that fiscal measures which are aimed at promoting the relative position of the poor would promote overall economic growth as well.

7.6 Sensitivity of the Results for some changes in the income coefficients for the Poor and the Rich.

So far, in all the alternative solutions income coefficients have been fixed at the ratios reflected in the 1970 data base. Now it would be useful to investigate the sensitivity of the results for some changes in the income coefficients. In particular, it would be interesting to see whether:

(i) it would be possible to differentiate Rawlsian solution from the Utilitarian solution by changing income coefficients,

and (ii) our main argument, that the relative income shares cannot be changed substantially by means of production planning, is maintained with some alternative income coefficients for the poor and the rich.

With these ends in mind, a wide range of experiments could be undertaken as there is no firm base for changing the income coefficients. However, the experiments have been restricted to just two:

(i) Income coefficient of Modern Industry for the rich is increased by 25% by reducing the income coefficient for the poor from 0.1205 to 0.0793 so that total value added coefficient of the Modern Industry remains unchanged. This could be interpreted as an introduction of a new technology by Modern Industry which is less labour intensive and provides more incomes for the rich.

(ii) Income coefficients for the poor and the rich in Other Agriculture are interchanged, i.e. instead of fixing income coefficient for the poor at 0.5562 and the rich at 0.2632, the poor's income coefficient is fixed at 0.2632 while that for the rich is fixed at 0.5562. This reversal of income coefficient introduces a new technology which could be considered as mechanizing of the Other Agricultural activities.

It should be noted that these changes are introduced one at a time and experiments are undertaken in the model with no taxes and subsidies on the households and without any public overhead investment.

Summary results pertaining to the distribution of income and utilities in the solution with increased income coefficient for the rich in Modern Industry are shown in Table 7.7.

TABLE 7.7.

INCOMES AND UTILITIES OF THE POOR AND THE RICH HOUSEHOLDS IN THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT AND NO TAXES AND SUBSIDIES ON HOUSEHOLDS, WHEN THE INCOME COEFFICIENT FOR THE RICH IN MODERN INDUSTRY INCREASED BY 25% REDUCING THE CORRESPONDING COEFFICIENT FOR THE POOR.

(at 1970 prices)

	1979 (Pre Plan Year)		1980	Growth rate %	1981	Growth rate %	1982	Growth rate %	1983	Growth rate %	1984	Growth rate %	Discounted Sum	
Total Disposable Income of Poor (Rs.mn)	7330	(45.90)	7355	0.34 (46.09)	7701	4.70 (45.99)	8730	13.36 (46.82)	9613	10.11 (47.29)	10059	4.64 (46.65)	35664	(46.56)
Total Disposable Income of Rich (Rs.mn)	7113	(44.54)	7137	0.34 (44.72)	7525	5.44 (44.94)	8288	10.14 (44.45)	8978	8.32 (44.17)	9618	7.13 (44.60)	34142	(44.58)
Utility of Poor (per households) ln	6.76125		6.76466	0.05	6.81063	0.68	6.93604	1.84	7.03239	1.39	7.07774	0.64	28.80614	
Utility of Rich (per household) ln	8.09781		8.10118	0.04	8.15412	0.65	8.25069	1.18	8.33066	0.97	8.39952	0.83	34.32870	
Gross Domestic Product at Producer Prices(Rs.mn)	15968		15959	-0.06	16745	4.92	18646	11.35	20328	9.02	21563	6.07	76592	

Income shares in GDP are reported within the brackets.

By increasing the income coefficient for the rich in Modern Industry, it was attempted to see whether the model could generate two different solutions for the Rawlsian and Utilitarian cases. However, even the present income coefficient for the rich in Modern Industry is lower than those in Other Agriculture and Services. Moreover, relative to Modern Industry, consumption demand by both the poor and the rich for the output of these sectors are very high. On the other hand, these sectors provide higher income for the poor as well. Therefore the model still does not differentiate Rawlsian solution from Utilitarian solution.

With the higher income coefficient for the rich in Modern Industry, a higher share of income for the rich might be expected. However, the increase does not seem to be very great. For example, if this new technology had prevailed in the pre plan year, then the income share of the rich would have been 44.54% compared with the share of 43.90% with old technology. Similarly, the income share of the poor would have been 45.90% compared with the share of 46.54% with the old technology. The important point is that these shares which would have arisen in the pre plan year, with the new technology, would not have changed substantially by the end of the planning period. In terms of the discounted sum of disposable incomes, the income share of the poor in discounted sum of GDP of 46.56% represents only 0.66 percentage point improvement in the poor's share. Similarly, the share of the rich increases by only 0.04 percentage points. These changes are accompanied by corresponding reduction in the income share of the other institutions. Therefore, our main argument still holds. Even with the new technology, optimal development process provides income for both the poor and the rich without changing the relative income shares substantially.

Compared with the old technology, the introduction of this new technology would have increased the discounted sum of GDP by 0.41%. This is due to the fact that this change in the technology makes it more advantageous to import modern industrial goods compared with the other importable goods. Therefore, the discounted sum of imports of Modern Industrial goods increase by 8.36% reducing that of Light Manufacturing goods by 8.09%. Accordingly the discounted sum of output of Modern Industry declines by 1.79% increasing that of Light Manufacturing by 1.90%. As the Light Manufacturing is highly dependent on Other Agriculture for indirect inputs, the discounted sum of output of Other Agriculture also increases by 0.97%. Changes in the other sectors are marginal. These differences in the pattern of output explain the slight (0.41%) increase in the discounted sum of GDP.

Given these two technologies, which should be selected? This, in fact, is a policy option and ought therefore to be chosen by the political authority. As analysts, we could help to make this value judgment, by providing the information summarised in Table 7.8.

TABLE 7.8.

Comparison of Results under the Two Different Technologies in Modern Industry.

	Old Technology	New Technology	% change
Discounted sum of:			
Disposable Income of Poor (Rs.mn)	35956	35664	-0.81
Disposable Income of Rich (Rs.mn)	33540	34142	1.78
Utility of Poor (per household, ln)	28.84383	28.80614	-0.13
Utility of Rich (per household, ln)	34.25568	34.32870	0.21
Gross Domestic Product (Rs.mn)	76281	76592	0.41
Income Share of:			
Poor (percentage)	47.14	46.56	-1.23
Rich (percentage)	43.97	44.58	1.39

However, if the political authority agrees to weight the utilities of the poor and the rich households according to the proportion of households in each group, then the old technology provides a weighted sum of discounted sum of utilities of the poor and the rich of ln 29.87208 compared to ln 29.85543 under the new technology. Therefore, under such conditions, it could clearly be decided to select the old technology. However, if the political authority decide to follow utilitarian principle, then the new technology would be selected.

The summary results pertaining to the distribution of incomes and utilities in the solution with reversed income coefficients for the poor and the rich in Other Agriculture are shown in Table 7.9.

The reversal of income coefficients for the poor and the rich in Other Agriculture represents an increase in the income coefficient for the rich from 0.2632 to 0.5562 and drop in the income coefficient for the poor from 0.5562 to 0.2632. However, even with such a large change in the income coefficients, the model does not differentiate the Rawlsian solution from the Utilitarian solution. Now Other Agriculture is relatively less profitable in terms of poor incomes. Yet, even if no weight is attached to the utility of the rich, the optimal growth process has to develop Other Agriculture not only because it has the third largest income coefficient for the poor but also since this sector has to meet a heavy demand by both the poor and the rich for consumption and by other sectors (mainly Light Manufacturing) for

TABLE 7.9.

INCOMES AND UTILITIES OF THE POOR AND THE RICH HOUSEHOLDS IN THE SOLUTION WITH NO PUBLIC OVERHEAD INVESTMENT AND NO TAXES & SUBSIDIES ON HOUSEHOLDS WHEN INCOME COEFFICIENTS OF THE POOR AND THE RICH IN OTHER AGRICULTURE ARE INTERCHANGED.

(at 1970 prices)

	1979 (Pre Plan Year)		1980	Growth rate%	1981	Growth rate %	1982	Growth rate %	1983	Growth rate %	1984	Growth rate %	Discounted Sum	
Total Disposable Income of Poor(Rs.mn)	6079	(38.07)	6198	1.96 (37.82)	6417	3.53 (37.66)	6946	8.24 (37.50)	7054	1.55 (37.48)	7246	2.72 (38.03)	28021	(37.69)
Total Disposable Income of Rich(Rs.mn)	8364	(52.38)	8682	3.80 (52.97)	9083	4.62 (53.30)	9935	9.38 (53.64)	10000	0.65 (53.13)	10000	0.0 (52.49)	39493	(53.12)
Utility of Poor (per household) ln	6.57412		6.59350	0.29	6.62823	0.53	6.70744	1.19	6.72287	0.23	6.74973	0.40	27.82365	
Utility of Rich (per household) ln	8.25982		8.29714	0.45	8.34229	0.54	8.43195	1.07	8.43847	0.08	8.43847	0.0	34.95313	
Gross Domestic Product at Producer Prices (Rs.mn)	15968		16390	2.64	17040	3.97	18520	8.68	18821	1.62	19052	1.23	74340	

indirect inputs. But the development of this sector now generates more income for the rich, which in turn increases the demand for Modern Industry which is more intensive in generating incomes for the rich. Therefore, even the Rawlsian solution has to develop sectors which are more intensive in generating incomes for the rich. As a result of this the model cannot differentiate Rawlsian solution from Utilitarian solution.

If this technology had prevailed in the pre-plan year, the income share of the poor in that year would have been 38.07% compared to 46.54% with the old technology. Similarly the income share of the rich would have risen to 52.38% compared to 43.90% under the old technology. The important point is that these income shares that would have prevailed in the pre-plan year with the new technology, would not have changed substantially by the end of the planning period. In terms of the discounted sum of income, the income share of the poor at 37.69% represents only a 0.38 percentage point drop in the pre-plan share while the share of the rich at 53.12% represents an improvement of 0.74 percentage point. These changes cannot be considered as substantial. Therefore our main conclusion that the relative income shares cannot be changed substantially by means of production planning, is still maintained.

Compared with the model solution with the old technology, the present solution represents a 12.06% and 4.15% reduction in the discounted sum of output of Other Agriculture and Light Manufacturing respectively.

The discounted sum of output of Modern Industry increases by a substantial percentage of 11.80% while that of Services increases by 1.17%. These changes should be interpreted in terms of the changed structure of the demand as the present solution generates relatively more incomes for the rich. As a result of this changed structure of the output, the discounted sum of GDP drops by 2.54% thereby reducing the discounted sum of income of the poor by 22.07% and increasing the discounted sum of income of the rich by 17.75%. Once again the problem of the choice of techniques arises. The basic result under the two techniques are summarised in Table 7.10, to facilitate the political authority in choosing a technique. However, in the present case, the choice is quite clear. The new technology provides benefits for only the rich. Even according to the Utilitarian principle the old technology is proved to be relatively much better.

TABLE 7.10.

Comparison of Results under the Two different Technologies in Other Agriculture.

	Old Technology	New Technology	% change
Discounted Sum of:			
Disposable Income of Poor (Rs.mn)	35956	28021	-22.07
Disposable Income of Rich (Rs.mn)	33540	39493	17.75
Utility of Poor (per household, ln)	28.84383	27.82365	-3.54
Utility of Rich (per household, ln)	34.25568	34.95313	2.04
Gross Domestic Product (Rs.mn)	76281	74340	-2.54
Income Share of:			
Poor (percentage)	47.14	37.69	-20.05
Rich (percentage)	43.97	53.12	20.81

CHAPTER 8.

Multiple Objective Decision Methods.

8.1 Introduction.

This chapter identifies multiple objectives of economic development and presents techniques to arrive at a solution to the multiple objective decision problem. In chapter 3, we argued that the objective function of a programming model for economy-wide development planning should be a social welfare function and presented a reasonable approximation for it. In the formulation of that objective function, we assumed that the social welfare depends entirely on consumption and its distribution. Therefore, that social welfare function itself incorporates two objectives of development. However, there we managed to combine these two objectives and thereby to provide a single criterion to evaluate the performance. Utilities of the poor and the rich household were combined using the proportions of the poor and the rich households as weights. However this approach is not always possible and our decision maker may not be willing to express his weights explicitly.[1)] On the other hand, assignment of weights or obtaining value judgments from the decision maker becomes more difficult as the number of objectives increases.

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1. "Most Governments would, in our opinion, desire that the distribution of income be taken into account. Many of their actions imply this. But to give quantitative expression to its preferences in this respect might be political dynamite." Little and Mirrlees (1974 p.54)

Our earlier assumption that welfare depends only on consumption and its distribution may not be quite appropriate. Therefore in section 8.2 we specifically examine the possible objectives of economic development. If the multiple objectives are to be realised from economic development and a single criterion which takes into account all of these objectives cannot practically be defined, it becomes necessary to survey and introduce techniques to handle multiple objective decision problems. The importance of multiobjective approach is discussed in section 8.3 while section 8.4 introduces the general features of multiple objective decision (MOD) methods. Basic concepts of MOD methods are presented in section 8.5 highlighting the importance of Pay-off Matrix and efficient solutions. As a solution to a multiple objective problem, a decision maker can be presented with at least a subset of efficient solutions. Therefore section 8.6 discusses techniques for generating efficient solutions and examines the advantages and disadvantages of this approach to a multiple objective problem. A few conceptualisations of compromise solutions are presented in section 8.7 examining the possibility of applying a global criterion to solve a multiple objective problem. Section 8.8 highlights the relative importance of interactive approach to a multiple objective problem and presents a specific variant of interactive multiple objective method in detail. Hierarchical Optimisation method is presented in section 8.9. Section 8.10 concludes the chapter.

8.2 Possible Objectives of Economic Development.

In general the objective of economic development is to maximize social welfare. However, if all the potential arguments which could appear in the social welfare function cannot be combined together to obtain a single criterion function, an alternative would be to identify each of the arguments as separate objectives. Then methods would have to be devised to do justice to the multiplicity of objectives.

We have already identified the objectives of consumption and distribution (Chapter 3). In addition a few more could be suggested and indeed appear in published plan documents in developing countries. For example, a partial list of objectives outlined by Loucks (1975) is reproduced below:[1)]

Some Objectives and Possible Units of Measurements.

Objectives.	Examples of Units of Measurements.
1. National Economic Growth	Discounted GNP, GDP, or terminal GNP, \$; increase in total income, \$; terminal capital stocks, \$.
2. Aggregate Consumption (Standard of living)	Discounted consumption or utility of consumption, \$.

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1. Loucks used the word goals instead of objectives.

Objectives.	Examples of Units of Measurements.
3. Income Distribution.	Total weighted sum of logarithms of consumption of each income class, Gini coefficient, Theil coefficient, coefficient of variation, relative mean deviation.
4. Price Stability.	Change in unit market or social price for various goods and services, $.
5. Self Reliance.	Balance of payments or trade deficit, $; employment of foreign labour, number or percent; discounted foreign exchange surplus, $; total imports, $.
6. Educational Opportunity.	School enrolments by grade, number or percent.
7. Productive Capacity.	Investments $.
8. Employment Level.	Total unemployment or underemployment weighted by income group, number or percent.
9. Regional Development.	Gross regional product or production, $; change in relative rates of aggregate or per capita growth in region, number or percent.

Objectives.	Examples of Units of Measurements.
10. Environmental Quality.	Mass and energy residuals discharged in air, water, and land; weight, volume, concentration, temperature, decibel level.
11. Social Mobility.	Sum of weighted change in employment by occupation, number or percent.

The above list contains commonly expressed objectives. However it may be questioned the admissibility of some of these objectives as independent objectives. Particularly this problem arises with respect to such objectives as national economic growth, production capacity, employment level and price stability. The problem is whether these are themselves objectives or just means of achieving the ultimate objective of higher standard of living and better distribution of consumption.[1)]

National economic growth measured by GDP or GNP has been given remarkable attention as an important objective. However, it might seem to be more appropriate to consider growth in GDP or GNP as a means for achieving ultimate objective of higher standard of living. As it was pointed out in UNIDO Guidelines for project evaluation:

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1. Dasgupta et al (1972), Little and Mirrlees (1974).

"To demand a high standard of living at a certain date in the future is, of course, equivalent to demanding a high growth rate starting from today's standard of living. Fundamentally, it makes no difference whether we wed ourselves to a high standard of living in the future or to a high growth rate, since they are equivalent." - Dasgupta et al (1972 p.101).

Particularly when the relationship between consumption and income is properly introduced within the model, separate maximization of aggregate consumption and income would yield uniform results. Therefore there is no need to introduce economic growth as a separate objective. Development planning becomes a problem with multiple objectives, only if the objectives are in conflict with each other.

Similarly, production capacity may not be considered as an independent objective. If production capacity is desired because of its role in making future consumption possible, then the objective of consumption has already taken this into account and therefore no separate consideration is required. On the other hand, it could be argued that national pride in developing economy may depend to a large extent, on the presence of modern machinery and other types of capital goods. If so, production capacity should be considered as a separate objective. However, this is an intricate issue because the question of national pride and related matters is a complex psychological one. It has to be determined whether this national pride arises from a recognition that these capital goods will raise the level of consumption in the future; if so, national pride arising in production capacity may be really a reflection of the future consumption prospects arising from them. On the other hand, if national pride takes the form of simply enjoying the possession of capital goods, then the presence of certain types of production capacities may be considered as merit wants. However, this seems to be a rather odd view to assume.

Price stability is apparently a short term objective of economic policy. However, it is not required on its own and therefore cannot be considered as an ultimate objective. If rapid inflation is harmful to consumption including the distribution of consumption, then it should be prevented. But the price level as such has no claim for consideration apart from its effect on the real standard of life. However, there is a related problem arising out of the instability of export prices of primary products. Primary product exporting developing countries have been badly affected by unfavourable terms of trade effects and face uncertainties with relation to their export earnings. Therefore positive action has to be taken to reduce these uncertainties. Usually results of planning models for developing countries would suggest specialization in primary products. This is not quite appropriate as it has not taken into account the uncertainties and related problems in primary exports. Therefore, as a way to overcome this problem, it is highly appropriate to diversify exports. Thus when we are working with a linear optimization model, it would be better to consider the maximization of industrial output as a separate objective. It should be emphasised that industrial production itself is not an ultimate objective. However, this would be a reasonable approach in overcoming the specialization in linear planning model and thereby reducing the uncertainties.

For some years,employment had been rather neglected in developing countries. Most of the formal development planning models did not pay much attention to the unemployment which is a critical problem in many developing countries. However, the importance of creating more employment opportunities has been increasingly recognised and most plan documents present this as one of their objectives. In planning for multiple objectives, it is worth examining the reasons why employment creation should be considered as a separate objective.

An existence of unemployment can be considered as a sign that important economic resources are being wasted. Therefore, the objective of employment creation may be related to the goal of a fuller exploitation of production potential. In this argument, employment is not desired for its own sake, but entirely as a means to the objective of production. Therefore in this view contribution of employment will be covered by the aggregate consumption objective and there is no need for considering employment as a separate objective.

However, apart from the above reason there are some more reasons why creation of more employment is desirable. According to the UNIDO

Guidelines for project evaluation:

"Unemployment has a deep and distressing psychological impact on society. Indeed most countries regard large-scale unemployment as a disaster. Lawlessness, vagrancy, crime and social disorder are closely associated with widespread unemployment. It could, therefore, be argued that employment is valuable in itself, quite apart from the contribution it makes to output creation." - Dasgupta et al (1972 p.86).

To some extent, concern with more employment is a concern about poverty. An unemployed family is also a poor family and in a society with widespread unemployment, there will tend to be greater inequality. Therefore employment creation may be considered not as an ultimate objective but as a means for distribution objective. Yet, psychologically, unemployment is a very disturbing phenomenon; quite apart from the income-creating implication of more employment there are also considerations of self-respect and self-confidence that relate to unemployment. Therefore even though creation of more employment opportunities is related with consumption and distribution objectives, there are sufficient reasons to consider it as an independent objective.

A worsening balance of payment position has been a major problem for many developing countries. Therefore any development planning effort has to take this into consideration. However, one may argue that improving the balance of payments position is not an ultimate objective. An improvement in the balance of payments position would permit a country to do several things to improve its standard of living. If that is so, the availability of foreign exchange is desired not for its own sake but for the sake of other objectives to which it contributes. However, the chronic shortage of foreign exchange and persistent balance of payment difficulties have made many developing countries thoroughly dependent on foreign aid, and the value of self-reliance has often been articulated in that context. Therefore it is more appropriate to consider self-reliance as an independent objective rather than a means to some other ends. It is indeed possible to argue that self-reliance is ultimately related to aggregate consumption and other objectives. However, in countries where chronic balance of payment difficulties are persistent, positive action should be taken to correct this. One of the appropriate ways to do this is to treat the improvement of balance of payments as a separate objective and to study the possible trade-off with other objectives. Such an approach could move towards a better compromise solution.

It is clear that there are some disagreements regarding the independency of some of the objectives given in Louck's list. However, this does not limit the importance of the approach we are suggesting in the rest of this chapter. Among others we have the objectives of aggregate consumption, income (consumption) distribution, employment, self-reliance and reduction of uncertainties. Moreover even if some objectives are theoretically not ultimate objectives, policy makers have to take those important considerations explicitly into account. Usually not only the level of the performance of objectives but also the level of the instruments (e.g. level of foreign aid, investment etc.) become arguments in policy makers preference function. Therefore within an optimization planning framework, there is no harm in treating such instruments as objectives.

8.3 Importance of Multiple Objective Approach.

A number of scientific methods have been developed to aid decision makers facing complex decision problems involving multiple, conflicting objectives. These methods have been called Multiple Objective Decision (MOD) methods or Multiple Objective Programming and Planning methods. They provide a very useful generalization of a more traditional, single objective approach to planning problems. The consideration of many objectives in the planning process accomplishes three major improvements in problem-solving (c.f. Cohon (1978, pp.2-4)).

1. Multiple objective planning and programming promotes more appropriate roles for the participants in the planning and decision making process. Programming and planning techniques are tools which an analyst may use to develop useful information for the decision makers. It is the contention here that traditional single objective approaches often expand the analyst's role, resulting in a decrease in the decision makers control of decision situation. A decision maker can

passively wait for the optimal solution to be determined by the analyst. In a multiobjective approach, relative values of all the plan effects are explicitly considered. By systematically investigating alternative plans, the range of choice and the relationship between alternatives and the relative values of the objectives are identified. In this manner responsibility of assigning relative values remains where it belongs, that is with the decision maker. Therefore multiobjective approaches are useful in promoting the explicit consideration of the value judgments which are implicitly made in the approaches of single objective. Moreover these approaches allow both the decision maker and the analyst to maintain appropriate roles in the process. The analyst is in the position of generating alternatives and trade-offs among objectives while important value judgments regarding the relative significance of the objectives are made by the decision maker.

2. When a multiobjective approach is followed, a wide range of alternatives is usually identified. Single objective approaches lead to the unambiguous identification of an optimal alternative. Therefore a decision maker is required either to accept or reject this single alternative identified as the best. Multiobjective approaches usually indicate decision makers a wide range of choice larger than one 'optimal' plan. The decision to accept or reject a single optimal alternative is an uninformed decision. Informed rational decision making requires a knowledge of the full range of possibilities. This is provided by the multiobjective approaches.

3. Finally, real world problems are multiobjective and therefore the imposition of a single objective approach on such problems is very restrictive and unrealistic. Multiobjective analysis allows several conflicting objectives to be treated without artificially combining them. This is a significant improvement in analytical capability.

8.4 General Features of Multiple Objective Decision Methods.

Even though the first contribution to MOD methods dates back to early fifties, the number of contributions remained relatively small until the late sixties. Only since the beginning of the 1970's has a large number of studies been published on this subject. Detailed surveys and discussions of the development of MOD methods can be found in Starr and Zeleny (1977), Keen (1977), Cohon (1978), Hwang and Masud (1979), and Rietveld (1980), among others. Some general features of MOD methods can be outlined as follows: (c.f. Rietveld 1980)

1. A decision maker (DM) faces a certain choice problem
2. The DM is assisted by an analyst who has the task of providing scientific assistance.
3. The DM evaluates the alternatives by means of a certain set of objectives he wishes to achieve.
4. The analyst has at his disposal information about the instruments to realise the objectives as well as the impact of the decision instruments on the objectives.

When the DM aims at attaining several conflicting objectives, an unambiguous optimal solution cannot be provided by the analyst unless the DM has accurately stated his priorities concerning the objectives. Alternatively, when the DM is unable to list his priorities, the analyst can generate a number of relevant alternatives from which the DM, after a certain deliberation phase, may select the desired one. It is very difficult to formulate one's priorities before one knows the relevant alternatives. On the other hand, if the DM does not specify any priorities at the beginning he will bear the full weight of the deliberation activities at the end of the process, which may be very heavy since the number of relevant alternatives generated is usually large.

In practice, the DM may give some provisional information on priorities at the beginning, and may revise them on the basis of information about the alternatives computed by the analyst. After each revision, the analyst computes additional information about relevant alternatives. The process only ends if the DM feels no further need to refine his former statement of priorities. Therefore there is a continuous exchange of information between the analyst and the DM. The analyst produces information about possibilities, while the DM produces information about desirabilities. Finally there will be a convergence of communications when the possibilities and desirabilities have been led to an agreement.

8.5 Basic Concepts in MOD Methods.

This section presents the channels open to an analyst to provide relevant information about the feasible solutions and their implicit trade-off to the DM. It is assumed that the DM's priorities are unknown. Therefore it will appear that the answer to this question is not straightforward. We start with a discussion about the generation of extreme options and then the concepts of efficient solutions will be presented subsequently.

8.5.1 The Pay-Off Matrix.

In general single objective approaches, the analyst has to solve the mathematical programming problem:

$$\text{(1)} \qquad \begin{aligned} &\text{Max } w_j(\underline{x}) \quad \text{for a certain } j \\ &\text{Subject to } \underline{x} \in S \end{aligned}$$

where $\underline{x}$ is the vector of instruments and S defines the feasible region.

In this case the only relevant information for the DM is the optimal set of instruments $\underline{x}_j^*$ and the corresponding value of the objective $w_j(\underline{x}_j^*)$. Even when there are alternative optima the optimal value of the objective function is unique.

This straightforward approach fails as soon as two or more objectives are being considered and this notion of optimality has to be dropped for multiobjective problems. A solution which maximizes one objective will not, in general, maximize any of the other objectives. What is optimal in terms of any one of the J objectives is usually non optimal for other $J-1$ objectives. A successive solution of (1) for $j = 1,\ldots,J$ leads to a series of different optimal solution vectors $\underline{x}^*_1,\ldots,\underline{x}^*_J$. The conflicting nature of the problem can be illustrated by means of the Pay-off Matrix P of order $J \times J$ of which J successive columns show the effects of the J instrument vectors $\underline{x}^*_j$ on the objectives,

$$P = \underline{w}(\underline{x}^*_1),\ldots,\underline{w}(\underline{x}^*_J)$$

where the element $P_{jj'}$ indicates the value of the j^{th} objective which results if the j'th objective were to be maximized.

<u>Pay-Off Matrix</u>

		Max $w_1(\underline{x})$	Max $w_2(\underline{x})$	....	Max $w_J(\underline{x})$
Outcome for					
	w_1	P_{11}	P_{12}		P_{1J}
	w_2	P_{21}	P_{22}		P_{2J}
	$\vdots$				
	w_J	P_{J1}	P_{J2}		P_{JJ}

The matrix P may be conceived as a concise description of J scenarios which focus on J different objectives. Each column of P presents the value for the relevant objective functions when a policy is chosen that aims at realising a maximum value for only one objective. Thus each column of P shows the consequences for all objectives of a policy, focusing on the maximization of only one objective and neglecting the other J-1 objectives. The matrix P has been introduced into the MOD theory among others by Benayoun et al (1970, 1971) and Belenson and Kapur (1973).

Two other concepts have also been introduced using the information given in P matrix. Let $\underline{w}^*$ be the main diagonal of P . Then $\underline{w}^*$ contains the maximum attainable values of the J respective objectives. In a similar way $\underline{\bar{w}}$ can be defined as the vector with minimum attainable values for the J objectives

$$\bar{w}_j = \min_{j'} (P_{jj'})$$

$\underline{w}^*$ and $\underline{\bar{w}}$ indicate between which bounds the ultimate solution will be realized. Each policy feasible within the framework of the model will result in an outcome $\underline{w}$. Obeying $\underline{w} \leq \underline{w}^*$. Thus $\underline{w}^*$ dominates all feasible solutions. Therefore it was given the name 'ideal solution.' Yu (1973)introduced it as the 'Utopia Point'.

The above three concepts play an important role in MOD methods. They enable the DM to form an impression of some essential elements of the decision problem.

8.5.2 Efficient Solutions.

The Pay-off matrix reflects only the extreme scenarios of the problem. To aid decision making it is very useful to provide information about intermediate solutions reflecting certain compromise among objectives. In the solution of a single objective problem optimality plays an important role and it allows the analyst and decision maker to restrict their attention to a single solution from among the much larger set of feasible solutions. The concept of efficiency has been introduced to serve a similar but less limiting purpose for multiobjective problems. The concept of efficiency is called 'nondominance' by some mathematical programmers, Pareto Optimality by welfare economists and 'noninferiority' by others. Efficiency is formally defined as follows.

$\underline{x} \in S$ is an efficient solution if there does not exist another feasible solution $\underline{\mathring{x}} \in K$ such that

$$w_j(\underline{\mathring{x}}) \geq w_j(\underline{x}) \qquad j = 1,\ldots,J$$

and

$$w_j(\underline{\mathring{x}}) \neq w_j(\underline{x}) \qquad \text{for at least one } j .$$

The problem of identifying efficient solutions has been called vector maximization problem. Early formulation of it could be found in Kuhn and Tucker (1951) and Karlin (1959). A formal presentation of the problem is:

$$\text{(2)} \quad \begin{array}{l} \text{Max} \quad \underline{w}(\underline{x}) \\ \\ \text{S.t.} \quad \underline{x} \in S \ . \end{array}$$

When there are multiple objectives, instead of looking for the optimal solution, we should search for efficient solutions. If no information on DM's preference could be obtained *a priori*, the analyst can present to the DM, at least a sub-set of efficient solutions to the vector maximization problem. From this sub-set the DM could choose the most satisfactory solution, making implicit trade offs between objectives based upon some previously unindicated criteria. Therefore in the next section we present methods for generating efficient solutions. The relative advantages and weaknesses of this approach to the MOD problem is also discussed.

8.6 Generating Techniques.

In general there are two different basic approaches to identifying efficient solutions (c.f. Cohon and Marks (1975)) i.e. by means of weights and by means of constraints (side-conditions).

The weighting method follows directly from the necessary conditions[1)]

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1. Kuhn-Tucker efficiency conditions: if a solution x to the vector maximization problem in (2) is efficient, then there exists $\lambda_j \geq 0$ $j = 1,\ldots,J$ (λ_j is strictly positive for some j) and $\mu_i \geq 0$ $i = 1\ldots m$ [m is the number of constraints $g(x)$] such that

$$\underline{x} \in S$$

$$\mu_i g_i(\underline{x}) = 0 \qquad i = 1,\ldots,m$$

and $$\sum_{j=1}^{J} \lambda_j \nabla w_j(\underline{x}) - \sum_{i=1}^{m} \mu_i \nabla g_i(x) = 0 \ .$$

These conditions are necessary for an efficient solution and when all of the $w_j(x)$ are concave and K is a convex set, they are sufficient as well.

of efficiency developed by Kuhn and Tucker (1951) and was the first technique developed for the generation of efficient solutions. Zadeh (1963) pointed out that the Kuhn-Tucker conditions imply that efficient solutions can be obtained by solving a scalar optimization problem, in which the objective function is a weighted sum of the components of the original vector-valued function $\underline{w}(\underline{x})$. Therefore the solution to the following problem is, in general, efficient.

$$(3) \qquad \begin{aligned} &\text{Max } \underline{\lambda}'\underline{w}(\underline{x}) \\ &\text{S.t. } \underline{x} \in S \end{aligned}$$

where $\underline{\lambda} \geq \underline{0}$ and λ_j is strictly positive for at least one objective. Therefore the analyst can, in principle, identify the set of efficient solutions by solving (3) through varying repeatedly and systematically the value of $\underline{\lambda}$.[1)] An example for $J = 3$ of such parametric programming operation would be to solve (3) for the following series of weight vectors:

$$(.8 \;\; .1 \;\; .1),\; (.7 \;\; .2 \;\; .1),\; (.6 \;\; .3 \;\; .1),\ldots\ldots,(.1 \;\; .1 \;\; .8) \quad .$$

In this way only a small subset of efficient solutions will be generated. Yet, this subset may be useful to obtain an impression of the whole set of efficient solutions. Further, once an efficient solution has been selected by the DM, this solution can be interpreted in terms of a certain combination of weights $\underline{\lambda}$. Therefore this method leads to an explicit quantification of trade-offs among objectives.

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1. This was initially demonstrated by Gass and Saaty (1955) for a two objective problem.

The constraints method operates by optimizing one objective while all of the others are constrained to some values. Marglin (1967 pp.24-25) appears to be the first to have suggested such an approach to multiobjective problems. Haimes (1973) presented this method as "ε constrained" method. Cohon and Marks (1975) described this method as the dual of the weighting method. This method also follows directly from the Kuhn-Tucker condition for efficiency.[1] Accordingly an efficient solution can be obtained by solving the problem:

$$(4) \qquad \begin{array}{ll} \text{Max} & w_j(\underline{x}) \\ \text{s.t.} & \underline{x} \in S \\ & \underline{w} \geq \underline{\tilde{w}} \end{array}$$

where $\underline{\tilde{w}}$ is a vector of constraint values for objectives.

Thus this formulation yields a scalar objective function. By parametrically varying $\underline{\tilde{w}}$, it is in principle, possible to generate all efficient solutions by means of (4).

Even though this method does not use weights on objectives, trade-offs among objectives are given by the shadow prices of the constraints $\underline{w} \geq \underline{\tilde{w}}$. Cohon and Marks (1973), Haimes and Hall (1974) and Miller and Byers (1973) utilized this property in their studies of water resources systems.

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1. For details see Cohon and Marks (1975) pp.211-212.

Weighted objective functions were introduced into public investment planning by Marglin in Maass et al (1962 pp.78-81) and by Marglin (1967 pp.23-24) and by Major (1969). The use of constraints to represent objectives in public investment planning also was introduced by Marglin (see Maass et al 1962 and Marglin 1967). However, the intent of these authors was not to generate the entire efficient set, since they identified only a single set of weights $\underline{\lambda}$ or $\underline{\tilde{w}}$ which were in some sense socially optimal. The 'switching value' method presented by Dasgupta et al (1972 pp.141-148) is another limited version of the weighting method.

In addition to the two methods discussed above, there are a few more methods developed to generate efficient solutions. Two examples are Adaptive Search method and Multiple Objective Linear Programming (MOLP) methods.[1)] These methods avoid the repetitive solution of a scalar version of a multiobjective problem which is required by the weighting and constraints methods. However, these methods are computationally inefficient for problems of large or even moderate sizes.

The purpose of the generating techniques is the identification of the set of efficient solutions within which the best compromise solution will lie. The basic virtue of the generating techniques

1. Adaptive Search method was suggested by Beeson (1971) and Beeson and Meisel (1971). Holl (1973), Evans and Steuer (1973) and Zeleny (1974) have presented specific simplex-based algorithms for the generation of efficient solutions.

is that it does not require a priori statement about preferences, priorities or any other value judgments about the objectives. The articulation of preference is deferred until the range of choice, represented by the efficient set, is identified and presented to the DM. It emphasises the trade offs among objectives over the entire range of feasibility. Therefore, in principle, the DM can make a very well informed decision.

The major weakness is that the generating techniques are sensitive to the number of objectives and becomes problematic if the number of objectives are larger than three. First computational effort may become very time-consuming. Secondly, even if it appears to be possible to calculate a representative subset of efficient points it is doubtful whether this procedure is useful for the DM because of his limited information - digesting capacity. When $J > 3$ display of results also become a problem of higher -dimensional problems and the analyst can no longer present the efficient set graphically. Therefore, the power of the method in graphically capturing the essence of the multiobjective problem is lost. Thus generating techniques produce a large number of alternatives and when the number of objectives become larger, it becomes almost impossible for the DM to choose one which is the most satisfactory. It would become a situation where the DM 'cannot see the woods for trees'.

8.7 Compromise Solutions.[1]

As we have already pointed out, generating techniques tend to produce a large number of alternatives. Therefore it is worthwhile considering the possibility of obtaining some efficient solutions. An example of such type of solutions is called compromise solutions. This is obtained by applying pre-determined criteria. Therefore this is known as the method of global criterion.

The idea of compromise solutions can be operationalised in various ways. Rietveld (1980) presents three conditions which should be satisfied by a compromise solution.

1. A compromise solution should be based on the notion that all J objectives are judged to be equally important.
2. A compromise solution should be efficient.
3. Extreme solutions such as the elements of P should not, as a compromise solution, receive more consideration than other intermediate solutions.

A number of conceptualizations of compromise solutions can be found in the recent literature. Only a few examples are presented below.

One of the approaches is to find the solution which has a minimum distance with respect to the ideal solution $\overset{*}{\underline{w}}$. This approach

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1. Rietveld (1980).

requires normalization of objective functions and an appropriate choice of a distance metric. A frequently used distance metric is the Minkovsky metric.

$$d = \sum_{j=1}^{J} (\overset{*}{w}_j - w_j)^p \qquad p \geq 1$$

which can be interpreted as a measure of distance (see Beckenbach and Bellman (1961) and Delft and Nijkamp (1977)).

The solution is sensitive to the value of p and for $p = 1$ and $p = 2$ the solutions are obtained by solving the following programming problems:

(5)[1]

$$\text{Min} \quad \underline{i}'(\underline{\overset{*}{w}} \;\hat{-}\; \underline{\overline{w}})^{-1}\{\underline{w} - \underline{w}(\underline{x})\}$$

$$\text{S.t.} \quad \underline{x} \in S$$

and

(6)

$$\text{Min} \quad \{\underline{\overset{*}{w}} - \underline{w}(\underline{x})\}'\{\overset{*}{w} \;\hat{-}\; \overline{w}\}^{-2}\{\underline{\overset{*}{w}} - \underline{w}(\underline{x})\}$$

$$\text{S.t.} \quad \underline{x} \in S \quad .$$

For $p \to \infty$ only the objective function with the dimension showing the largest difference are important. Then the corresponding programming problem is,

(7)

$$\text{Min} \quad \underset{j}{\text{Max}} \; \left(\frac{\overset{*}{w}_j - w_j(\underline{x})}{\overset{*}{w}_j - \overline{w}_j} \right)$$

$$\text{s.t.} \quad \underline{x} \in S$$

---

1. $\wedge$ indicates a diagonal matrix formed from the vector $(\overset{*}{\underline{w}} - \underline{\overline{w}})$

The problem with this approach is to determine that p which would result in the most satisfactory solution to the DM. It is also possible that whichever p is chosen, it might give a solution which has a particular objective value that is totally unacceptable to the DM.

Another approach is to find a solution which is optimal with respect to a set of weights reflecting a compromise in some way. There are various ways to attain such a compromise weights vector.

1. If all the objectives are given the same weights, then the programming problem (taking into account the different scales of measurement) will be,

$$(8) \quad \text{Max } \{\frac{1}{J}\, \underline{i}'(\underline{\overset{*}{w}} \, \underline{\hat{}} \, \underline{\bar{w}})^{-1}\}\underline{w}(\underline{x})$$

2. Define the weights according to the equal valuation of all extreme solutions of the P matrix. (c.f. Nijkamp and Rietveld (1976a and 1976b) and Nijkamp (1977)) i.e. weights are expressed by the vector $\underline{\lambda}$:

$$(9) \quad \begin{array}{l} P'\underline{\lambda} = c\underline{i} \\ \underline{i}'\underline{\lambda} = 1 \end{array} \qquad \text{when } c \text{ is a constant}$$

and (9) implies that

$$\underline{\lambda} = \frac{(P')^{-1}\underline{i}}{\underline{i}'(P')^{-1}\underline{i}} \tag{10}$$

$$c = \frac{1}{\underline{i}'(P')^{-1}\underline{i}}$$

provided P is non-singular.

Therefore the programming problem is to find the solution of[1)]

$$\text{Max} \quad \frac{(P')^{-1}\underline{i}}{\underline{i}'(P')^{-1}\underline{i}} \quad \underline{w}(\underline{x}) \tag{11}$$

$$\text{s.t.} \quad \underline{x} \in S \ .$$

These are only a few examples of compromise solutions. Although these type of compromise solutions can provide some guidance to the DM, there is no guarantee that the DM will be satisfied with any of these compromise solutions. Therefore these types of compromise solutions cannot be considered as final solution to the multiobjective programming problem. In fact a compromise solution is a starting point for more appropriate (practical) decision methods which are known as "Interactive Multiple Objective Decision Methods".

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1. This approach is quite appealing. However, Rietveld (1980 p.121-126) shows that in certain cases, this compromise weight vector may contain negative elements. Therefore he suggests another method to obtain a compromise weight vector which is based on a game theoretic interpretation of the P matrix.

8.8 Interactive Multiple Objective Programming Methods.

The main difficulty in the presence of multiple objectives is the DM's inability to articulate his preferences on objectives a priori. Generating techniques seem to have simplified the problem by providing the set of efficient solutions without a priori preference information, but as we have already seen, the efficient set is normally unmanagable for the DM in practice. Therefore Interactive Multiple Objective Programming methods have been developed to overcome this difficulty.

Interactive methods assume that the DM is unable to indicate a priori preference information, but that he is able to provide preference information on a local level to a particular solution. The kind of local preference information required varies for each interactive procedure. In some methods the DM has to give his local trade-offs with respect to the objective values of the solution concerned. In other methods, the DM has to indicate whether a given solution is acceptable or not, and if not which of the objective values should be changed.

In general basic feature of the interactive methods is that the interaction consists of a number of steps, while in each step the following two elements are present:

(1) The analyst presents a provisional solution to the DM .

(2) The DM expresses his opinion about the provisional solution.

Therefore the DM has to express his local preference with respect to a series of solutions, which are presented to him in a stepwise manner and are partly the results of his previous answers. Interaction continues until a satisfactory solution is reached. During the interaction, it may be possible that the DM wishes to repeat the process considering errors and learning effects. Further, because of the new insight obtained during the interaction, it may even become necessary to revise the model.

An obvious advantage of the interactive approach is that there is no need for a priori preference information. The DM only has to express his preference based on a well-defined solution which is known to exist and to be feasible. If a priori preference information were required, he had to provide preferences without knowing the alternatives and feasibilities.

In the interactive approach, the DM is also a part of the solution process, and therefore the solution finally chosen has a better chance of being implemented. As the DM is closely involved in the solution process, he can attain more insight into the decision problem. The feedback process inherent in interactive procedure leads to a closer cooperation between the DM and analyst.

Therefore, the interactive approach can be considered as a powerful tool in decision situations where the DM's preferences are not known a priori. It also provides the benefit of learning effects and involves a closer cooperation of the DM in the solution process. In the subsection (8.8.1) we briefly introduce the different types of interactive methods while the subsection (8.8.2) presents a particular interactive method in detail.

8.8.1 A Brief Survey of Interactive Methods.

A considerable number of authors have contributed to the study of interactive programming methods. These methods differ in many respects. However, the basic structure is very similar. All interactive procedures progress from one solution to another guided by the desire of the DM. Considering the nature of the preference information to be given at each iteration by the DM, Spronk (1980) subdivided the set of available interactive procedures as follows:

(a) Methods in which the DM has to determine trade-offs among the objectives at each interaction, given the objective values in the current solution.

(b) Methods in which the DM has to choose the 'best' solution from a limited set of (generally efficient) solutions at each iteration.

(c) Methods in which the DM at each iteration has to define minimum or maximum values for one or more of the objectives, which in most methods are translated into restrictions reducing the feasible region.

The intention is not to provide a complete survey of interactive methods: a detailed survey is given by Hwang and Masud (1979) while Rietveld (1980) provides a concise survey. Instead, methods typical of methods while the subsection (8.8.2) presents a particular interactive method in detail.

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The intention is not to provide a complete survey of interactive methods: a detailed survey is given by Hwang and Masud (1979) while Rietveld (1980) provides a concise survey. Instead, methods typical of each type are briefly introduced so as to highlight the features of the method ultimately selected for an application in economy-wide development planning.

Type (a) methods provide a mechanism to find trade-offs among the objectives by interacting with the DM. A well-known example of this type is the method of Geoffrion (Geoffrion et al 1972). Even though it is difficult to obtain trade-off ratios when there are many objectives, Geoffrion method believes that DM can rather easily assess the trade-off between two objectives on a specific achievement level of the objectives. Therefore the improvement of an overall utility function through successive trade-off can be made by using an efficient interactive optimization technique. This method demonstrates that a large-step gradient algorithm can be used for solving multiobjective programming problems if the DM is able to specify an overall utility function defined on the values of the objectives. However, it is not actually required to identify this utility function explicitly. The optimization procedure used, in this case the Frank-Wolfe algorithm,[1)] determines the kind of information required. The algorithm proceeds from solution to solution via the 'steepest ascent' direction, i.e. the direction with maximum marginal increase in the overall utility function. It also requires knowledge about the maximum step-size in this direction.

---

1. This is a specific non-linear programming algorithm. For details see Frank and Wolfe (1956).

Both kinds of data are to be found with the help of the DM.

This procedure is very complicated as it relates interactive procedures to gradient methods. Thus, the DM may find difficulty in providing interactive information for the analyst. Also, some times it is not easy to choose the reference objective when the number of objectives become larger than three. The precise nature of the interaction with the DM is obscure.[1)]

Zionts and Wallenius (1976) provided a good example of type (b) methods.[2)] They assumed that the DM has an implicit utility function, on the basis of which he gives his answers to the analyst's questions. In this method, the DM is presented with a starting solution, which is arbitrarily chosen from the efficient set, and a set of adjacent corner solutions. Then the DM has to compare his preference for the starting solution with his preference for each of its neighbours. From this preference information, a new solution is derived which, with its neighbours, is again presented to the DM and so forth.

This method is attractive since the demand on the DM's ability to express his preference is relatively small. However, this method

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1. Another example of this type of method is the Surrogate Worth Trade-Off Method proposed by Haimes et al (1974, 1975). Even with this method the assessment required from the DM become excessive as the number of objectives become larger.

2. Another example is the Interactive MOLP method provided by Steuer (1977, 1978) which is an extension of the MOLP method.

requires that the constraint set and objective functions must be linear or feasible for linear approximation. As Hwang and Masud (1979 p.168) pointed out,

"The linear utility function assumption is quite a severe one, it may be relaxed to an assumption of an additive separable utility function of objectives. When it is relaxed to concave utility functions, the number of questions and iterations are significantly increased."

There are a number of contributions to Type (c) methods. In general they all start with the calculation of a compromise solution. In this respect the concepts of the distance metric has been used by Benayoun et al (1971) ane Fichefet (1976). Compromise weights have been applied by Nijkamp and Rietveld (1976a). Given such a compromise solution, the DM has to define a set of objective levels or relaxation of the levels in the compromise solution, which are then translated into restrictions and added to the underlying programming model. Then a new compromise solution is calculated and so forth.

Quite a number of interactive procedures are based on the procedure developed by Benayoun et al (1971) which is known as the STEM method. In this method, given a compromise solution $\underline{\mathring{w}}$, if some objective values are satisfactory and others not, the DM has to define a certain amount of relaxations ΔW_k for objectives k , the values of which are already satisfactory.

It is clear that compared to Type (a) and (b), Type (c) methods are relatively easy to apply and less demanding on the DM's ability to provide preference information. Within Type (c) methods STEM method is quite attractive, but it would be better if the DM is not required to define relaxation levels (ΔW_k). In this sense the procedure presented in Rietveld (1980), although based on STEM, is preferable as it does not require the DM to define ΔW_k . Therefore, in the next sub-section this procedure is presented as a potential and preferable method for an application in economy-wide development planning.

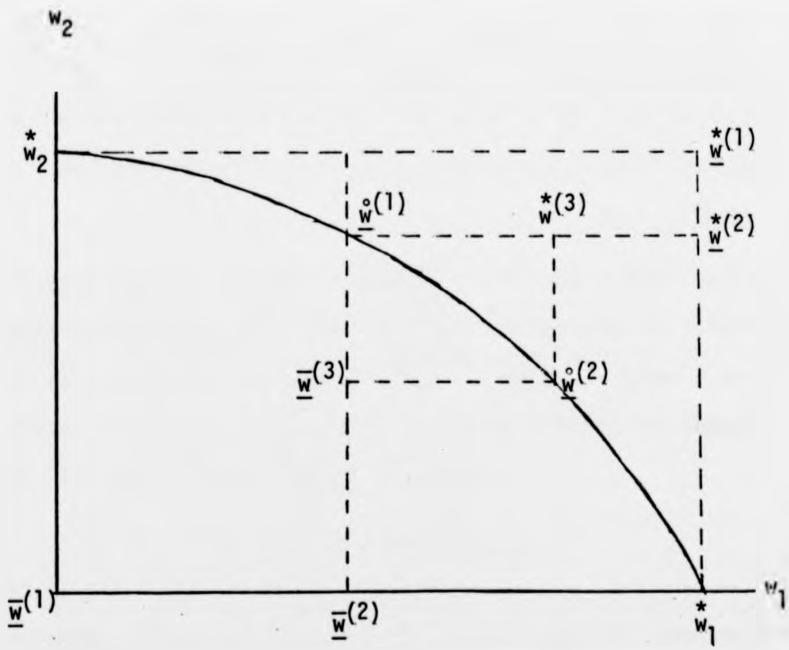
8.8.2 Interactive Programming by Imposing Side-conditions.

The core of this procedure as presented by Rietveld (1980) is as follows:

Stage (a) - The analyst solves a mathematical programming problem in order to find the pay-off matrix P and the vectors with minimum and maximum attainable levels for the objectives, $\underline{w}$ and $\overset{*}{\underline{w}}$. He calculates one of the compromise solutions $\overset{\circ}{\underline{w}}$ and the solution is presented to the DM with $\underline{\bar{w}}$ and $\overset{*}{\underline{w}}$.

Stage (b) - The DM mentions the objectives with unsatisfactory levels in $\overset{\circ}{\underline{w}}$. If all objectives are satisfactory, the procedure can be terminated. If all objectives in $\overset{\circ}{\underline{w}}$ are unsatisfactory, the problem does not allow an acceptable solution. If only some objectives are unsatisfactory, the analyst must add constraints to the mathematical programme, indicating that the performance of these objectives should be better in $\mathring{\underline{w}}$. The next step is then to return to Stage (a).

The essential characteristics of this procedure can be illustrated using the following diagram which is obtained from Rietveld (1980).



In the first step, the analyst identifies the P matrix and vectors $\bar{\underline{w}}$ and $\overset{*}{\underline{w}}$. Denote $\overset{*}{\underline{w}}$, $\bar{\underline{w}}$, $\mathring{\underline{w}}$ for step s as $\overset{*}{\underline{w}}^{(s)}$, $\bar{\underline{w}}^{(s)}$ and $\mathring{\underline{w}}^{(s)}$. The curve $\overset{*}{w}_2$-$\overset{*}{w}_1$ indicates the set of all efficient solutions. One of these solutions, $\mathring{\underline{w}}^{(1)}$, is selected as a provisional solution.

Now the DM has to answer the question of whether he prefers an improvement of the first objective or the second one. If the DM prefers an improvement of the first objective, the side condition, $w_1 \geq \overset{\circ}{w}_1^{(1)}$ is imposed on the original mathematical programme. In the other case, the side condition would be $w_2 \geq \overset{\circ}{w}_2^{(1)}$.

Assume that the DM prefers an improvement of $\overset{\circ}{w}_1^{(1)}$. Then in the second step, vectors $\underline{\overline{w}}^{(2)}$ and $\underline{\overset{*}{w}}^{(2)}$ are found. This represents a smaller maximum value for w_2 and larger minimum value for w_1 . The new compromise solution $\underline{\overset{\circ}{w}}^{(2)}$ shows a larger value for w_1 as was required by the DM. If now, the DM prefers an improvement of the second objective, the side condition $w_2 \geq \overset{\circ}{w}_2^{(2)}$ is added.

Therefore, in the third step, values for $\underline{\overline{w}}^{(3)}$ and $\underline{\overset{*}{w}}^{(3)}$ are found which form together a square which is only a small part of the square implied by $\underline{\overline{w}}^{(1)}$ and $\underline{\overset{*}{w}}^{(1)}$. This provides an illustration of the result that the procedure does converge.[1] After a certain number of steps, so little room for improvements of the objectives is left that a further search is pointless.

This procedure is quite general and can be applied to linear as well as non-linear problems. Given the fact that this method does not seem too demanding with respect to the DM's ability to cooperate, this method is considered as a promising candidate for application in economy-wide development planning.

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1. For formal proof of convergence see Rietveld (1980 pp.196-200).

8.9 Hierarchical Optimisation Method.

So far methods were presented under the assumption that no preference information can be obtained a priori. However, if the preference information can be obtained a priori, the problem can be simplified to a great extent. If the DM can specify his utility function $U(\underline{w})$, over objectives, a unique optimal solution could be obtained. Unfortunately the determination of $U(\underline{w})$, even for a simple problem is very difficult. On the other hand, if the DM can specify a set of goals for each objective he wishes to attain, then a preferred solution can be determined by minimizing the deviations from the set of goals.[1)] However, it is really doubtful that the DM is in a position to provide this kind of cardinal information, particularly in case of economy-wide development planning.

However, there may be situations where the DM is in a position to rank his objectives according to their importance. Such cases can be handled without using any concepts of compromise solutions. The procedure is known as Hierarchical Programming method (c.f. Haimes and Hall (1974) and Waltz (1967)).

In this method, the objectives are ranked in order to importance, $(w_1, w_2, \ldots, w_J)$. Then the optimization procedure requires the

---

1. This follows the Goal Programming method originally proposed by Charnes and Cooper (1961) and further developed by Ijiri (1965), Lee (1972) and Ignizio (1976) among others.

following stages:

Stage 1.

$$
(12) \qquad \begin{array}{ll} \text{Max} & w_1(\underline{x}) \\ \text{s.t.} & \underline{x} \in S \ . \end{array}
$$

Stage 2.

$$
(13) \qquad \begin{array}{ll} \text{Max} & w_2(\underline{x}) \\ \text{s.t.} & \underline{x} \in S \\ & w_1 \geq \beta_1 \mathring{w}_1(\underline{x}) \end{array}
$$

Stage 3.

$$
(14) \qquad \begin{array}{ll} \text{Max} & w_3(\underline{x}) \\ \text{s.t.} & \underline{x} \in S \\ & w_1 \geq \beta_1 \mathring{w}_1(\underline{x}) \\ & w_2 \geq \beta_2 \mathring{w}_2(\underline{x}) \qquad \text{etc.} \end{array}
$$

where $\mathring{w}_1(\underline{x})$ and $\mathring{w}_2(\underline{x})$ are the optimal values of $w_1(\underline{x})$ and $w_2(x)$ from (12) and (13) respectively. β_1 and β_2 are the corresponding parameters defining a tolerance area for $w_1(\underline{x})$ and $w_2(\underline{x})$ during the next stages $(\beta_1, \beta_2 \leq 1)$.

In this way, lower-order objectives are only considered after higher order objectives. This method has been extensively developed and applied to a regional growth and environmental policy problem in Delft and Nijkamp (1976). They also derived a procedure to overcome one of the less satisfactory features of the present method, whereby the specification of β parameters can introduce a certain amount of arbitraryness into the solution. Delft and Nijkamp (1976) suggested finding a best compromise solution by minimizing the relative discrepancies between the actual unknown $\underline{w}(\underline{x})$ and optimal known $\overset{*}{\underline{w}}(\underline{x})$ values of all objective functions, subject to a hierarchical ranking of the successive relative discrepancies. The basic assumption underlying this rank order is that a certain percentage deviation of an actual value of an objective function with respect to its optimal value is considered to be more serious for objective 1, than for objective 2 etc. Therefore the problem becomes

$$\text{Min} \sum_{j=1}^{J} \left| \frac{\overset{*}{w}_j - w_j(\underline{x})}{\overset{*}{w}_j} \right|$$

$$\text{(15)} \qquad \text{s.t.} \quad \underline{x} \in S$$

$$\left| \frac{\overset{*}{w}_j - w_j(\underline{x})}{\overset{*}{w}_j} \right| < \left| \frac{\overset{*}{w}_{j+1} - w_{j+1}(\underline{x})}{\overset{*}{w}_{j+1}} \right| \quad \text{for } j=1,\ldots,J-1$$

$$w_j \leq \overset{*}{w}_j$$

Now the original hierarchy between objective functions has been transferred into a hierarchy between constraints. Given the pre-specified hierarchical rank order of objectives this procedure always leads to a unique best compromise solution.

8.10 Concluding Remarks.

Multiple objectives in economic development were identified and methods which have been developed recently to handle multi-objective problems were briefly surveyed. As has been pointed out, in the presence of multiple objectives it is not possible to obtain an optimal solution. Instead, based on the DM's judgment, the most satisfactory compromise solution should be selected within the set of efficient solutions. In this respect, the importance of 'generating techniques' was discussed. However, generating techniques produce a large number of efficient solutions and therefore, when the number of objectives become large, it becomes almost impossible for the DM to choose one which, in some sense, is most satisfactory. The possibility of applying a global criterion was also discussed and it is pointed out that it may not necessarily provide a solution to the satisfaction of the DM. Therefore, as an alternative technique, Interactive Programming methods were introduced and their importance was examined. Various types of interactive programming methods were discussed, mainly to highlight the elegance of a particular method, namely Interactive Programming with imposing side conditions. This was selected as an especially suitable method for applications in economy-wide development planning. The importance of Hierarchical Optimisation methods in situations where objectives can be ranked, was also pointed out.

In the next chapter we demonstrate the applicability of the selected interactive method and the Hierarchical Optimisation method in multisectoral economy-wide development planning. Both methods are applied to highlight their relative features and performance.

CHAPTER 9.

Multiple Objective Decision Methods: An Application in Economy-Wide Development Planning.

The previous chapter identified the multiple objectives of economic development and presented methods to arrive at a solution to the multiple objective problem. The present chapter demonstrates the applicability of multiple objective decision (MOD) methods in economy-wide development planning. In particular, the applicability of Hierarchical and Interactive Programming methods is considered. Obviously, the optimum development strategy is conditional upon the specified objective. Therefore, different objectives may suggest different strategies of development. The present chapter first examines the conflicting or complementary nature of the objectives and the optimal development strategy suggested by each of the objectives. Given these different strategies of development, multiple objective decision methods are used to derive a possible unified strategy of development, taking into account all the objectives considered. Five objectives of economic development have been selected as being broadly representative of the range of possibilities:

1. Maximization of discounted sum of total income (i.e. Gross Domestic Product). This is equivalent to the maximization of aggregate private consumption since the consumption of households is directly related to their disposable income.[1)]

---

1. The notation in these objectives is defined in Table 3.1.

$$\text{Max } Y = \sum_{t=1}^{5} [V'X(t) + VG(t)]/(1+w)^{t-1} \quad .$$

2. Maximization of discounted sum of disposable income of the poor households.

$$\text{Max } YP = \sum_{t=1}^{5} [(1-t_p)\{V_p'X(t)+VG_p(t)\}]/(1+w)^{t-1} \quad .$$

3. Maximization of total employment over the five year period.

$$\text{Max } EMP = \sum_{t=1}^{5} \ell'X(t) \quad .$$

4. Maximization of discounted sum of industrial output.

$$\text{Max } ID = \sum_{t=1}^{5} [X_{t3} + X_{t4}]/(1+w)^{t-1}$$

where X_{t3} and X_{t4} are outputs of Light Manufacturing and Modern Industry in year t .

5. Minimization of discounted sum of the balance of payment deficits. This is equivalent to the minimization of discounted sum of total imports because exports are exogenously specified.

$$\text{Max}(-M) = -\sum_{t=1}^{5} [i'M''(t) + m'X(t)]/(1+w)^{t-1} \quad .$$

For the present application, the basic model specified in Chapter 3 is used without any modification except those modifications which relate to the objective function. Thus, instead of the non-linear objective function which was specified in Chapter 3 and used in Chapters 5, 6 and 7, now there are five (linear) objective functions. These five objectives are flexible in the sense that the values of these objectives are determined through the use of MOD methods, but it should also be noted that there are two fixed objectives as well, namely, public overhead investment and terminal capital stocks. Levels of these objectives have to be fixed a priori before any application of the MOD methods. As was noted in Chapter 5, the targets on these fixed objectives implicit in the Public Investment Programme can not be jointly achieved. They are jointly infeasible targets. Thus only 37.18% of the target level of public overhead investments can be incorporated with full target levels of terminal capacities while the full target levels of public overhead investment can be incorporated only with reduced levels of targets on terminal capacities, without losing the feasibility of a solution. Therefore, for the present application, it has to be decided a priori, at which levels these fixed objectives should be fixed. The two extreme possibilities are either to reduce the targets on terminal capacities and incorporate 100% of the target levels of public overhead investment or to incorporate full targets on terminal capacities without any public overhead investment. In preliminary experimentation both of these options were attempted and it was found that the model with the full targets on terminal capacities and no public overhead investment provided more flexibility among objectives compared to the model with reduced targets on terminal capacities and 100%

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public overhead investment. It is indeed quite possible to consider other alternatives such as some public overhead investments with reduced target on terminal capacities or 37.18% public overhead investment without reducing the targets on terminal capacities; but it would invariably reduce the degree of flexibility among 'flexible' objectives. As the present work mainly aims at demonstrating the applicability of MOD methods, it was decided to keep the model as flexible as possible by opting for the scenario with no public overhead investment but full targets on terminal capacities.

9.1 Evaluation of each of the objectives individually.

The main results of the evaluation of each of the objectives individually are summarised in the Pay-off Matrix below:

TABLE 9.1.

Pay-off Matrix

	Max Y	Max YP	Max EMP	Max ID	Max (-M)
Outcome:					
Y(Rs.mn)	78846	78784	78778	72599	75430
YP(Rs.mn)	38645	38799	38798	34813	36850
EMP('000)	24494	24751	24754	22021	23393
ID(Rs.mn)	35885	35906	35906	38687	36458
-M(Rs.mn)	-20818	-20818	-20818	-20818	-18586

In the pay-off matrix, each column shows, effects on all objectives, if a certain objective is optimized. Obviously, for each objective the outcome is at least as good when that objective is being optimized as it is when some other objective is being optimized. Vectors of maximum ($\underline{w}^*$) and minimum ($\underline{\bar{w}}$) attainable values of the objectives are derived from pay-off matrix and reported below.

$$\underline{w}^* = \begin{bmatrix} 78846 \\ 38799 \\ 24754 \\ 38687 \\ -18586 \end{bmatrix} \qquad \underline{\bar{w}} = \begin{bmatrix} 72599 \\ 34813 \\ 22021 \\ 35885 \\ -20818 \end{bmatrix}$$

$\underline{w}^*$ reflects the ideal solution which we know is not feasible. With respect to the 'total income', 'poor income' and 'total employment' objectives, the minimum attainable values are reported when the discounted sum of industrial output is maximized while the worst outcome for the balance of paymentsobjective is reported in all the approaches except in optimizing the balance of payments objective itself. Maximization of the discounted sum of total income yields the minimum attainable value for the industrial output objective.

A high degree of uniformity can be seen in the results of maximization of three objectives, namely the discounted sum of total income, of poor income and total employment. However there are some trade-offs, thus indicating a conflict among these three objectives, but they appear to be very marginal. For example the maximization of the discounted sum of total income (Max Y approach) yields a discounted sum of poor incomes amounting to Rs. 38645 mn. This is improved only by 0.40% when the discounted sum of poor income (Max YP approach) instead of total income is maximized. The corresponding decline in the discounted sum of total income is only 0.07%. Similarly, differences in the effects on other objectives are also marginal except in the case of total employment where the objective of maximizing poor income results in a larger but still unsubstantial improvement of 1.05% in total employment compared with the amount of total employment generated when total income is maximized. This close correspondence between the results of Max Y and Max YP approaches are due to the structural features of the economy. This is precisely the same situation which was observed in Chapter 7, in which we explained the inability of the economy to differentiate between the Utilitarian and Rawlsian solutions. The concept of a Rawlsian solution is equivalent to the maximization of poor income. The essential difference in the present application is that the non-linear objective function has been replaced by a linear form. The concept of a Utilitarian solution is very close to that of maximising the discounted sum of total incomes, except that in the present application, total income contains incomes of other institutions as well as households. However, in the previous application, the Utilitarian solution contains only the total disposable income of poor and rich households. Therefore, the positive links between poor and rich incomes, which were highlighted in Chapter 7, also explain the positive link between total income and poor income. This can be further examined by looking at the sectoral composition of the gross domestic output under the two different approaches of Max Y and Max YP. These are reported in Table 9.2.[1)]

As can be seen, sectoral composition of the output under Max Y and Max YP approaches are very close to each other; particularly in the first three years. However, in the last two years, Max YP approach expands the Other Agriculture sector relatively more and the Mining & Construction sector relatively less, compared with the Max Y approach. Apart from this, other differences are marginal. In terms of the discounted sum of output, differences in the shares of even the Other Agriculture and Mining & Construction are only of the order of 0.90 and 1.11 percentage points.

Therefore, the strategy of development suggested by both approaches are very close to each other. Each approach places more emphasis on Other Agriculture and agriculture based Light Manufacturing industries and less emphasis on Modern Industries. Under the Max Y approach, the share of Other Agriculture increases from 21.28% in 1980 to 24.54% by 1983, even though it declines slightly to 23.74% in 1984. Similarly, under Max YP approach, it increases from 21.29% in 1980 to 26.61% by 1983, though it drops slightly to 26.31% in 1984. In contrast, the share of Modern Industry drops from 11.70% in 1980 to 8.63% in 1983 and increases only up to 10.02% in 1984 under Max Y approach and drops from 11.71% in 1980 to 8.74% in 1983 and then increases only up to 9.96% in 1984 under Max YP approach. Therefore, the optimum development strategy under both of the approaches are similar, apart from the slight differences in the degree of emphasis on Other Agriculture and Mining & Construction.

---

1. In reporting the results of experiments conducted in this chapter, only sectoral shares of output are examined. Obviously, a decline (increase) in a sector's share does not necessarily indicate a decline (increase) in the level of output as well. However, comparison of sectoral shares do indicate on which sectors each approach places emphasis.

TABLE 9.2.

Sectoral Composition of Domestic Output under the Individual Optimization of the Objectives of Total Income, Poor Income and Total Employment.

(Percentages)

	1980			1981			1982			1983			1984			In Terms of Discounted Sum of Output		
	MaxY	MaxYP	MaxEMP	MaxY	MaxYP	MaxEMP	MaxY	MaxYP	MaxEMP	MaxY	MaxYP	MaxEMP	MaxY	MaxYP	MaxEMP	MaxY	MaxYP	MaxEMP
Tea & Rubber	5.12	5.27	5.27	5.08	5.04	5.05	4.54	4.62	4.62	4.14	4.20	4.20	4.12	4.13	4.16	4.60	4.65	4.66
Other Agriculture	21.28	21.29	21.29	21.73	21.54	21.55	23.85	23.88	23.87	24.54	26.61	26.56	23.74	26.31	26.31	23.05	23.95	23.94
Light Manufacturing	18.87	18.87	18.87	19.63	19.46	19.46	23.16	23.11	23.09	22.82	23.43	23.45	21.44	21.72	21.72	21.21	21.33	21.33.
Modern Industry	11.70	11.71	11.71	12.18	12.07	12.07	10.13	10.31	10.31	8.63	8.74	8.75	10.02	9.96	9.95	10.50	10.54	10.54
Mining & Construction	10.49	10.60	10.59	10.94	11.27	11.26	8.73	8.49	8.52	10.63	7.71	7.72	9.99	7.21	7.19	10.15	9.04	9.04
Services	32.54	32.26	32.27	30.44	30.62	30.61	29.59	29.59	29.59	29.24	29.31	29.32	30.69	30.67	30.67	30.49	30.49	30.49
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Differences between the Max YP and Max EMP approaches are negligible. Max EMP approach provides Rs.78778 mn. of discounted sum of total incomes which is only 0.01% less than that obtained under the Max YP approach. Compared with the Max YP approach, the Max EMP approach provides only a 0.01% improvement in total employment. The difference in the discounted sum of poor income is only Rs. one million and the effects on the balance of payments and industrial output objectives are exactly the same. This confirms a close resemblance between the distributive objective and employment objective. As has been pointed out in Chapter 8, it is possible to provide reasons to justify the independence of the employment and distributive objectives. However, in practice, at least based on this Sri Lankan case study, both maximization of either of the objectives suggests broadly the same development strategy. This is highlighted by a comparison of the sectoral compositions of outputs under Max YP and Max EMP approaches reported in Table 9.2. There is hardly any difference between these two particular compositions. Similarly, although there is some trade-off between total income objective and employment objective, the resulting differences in terms of development strategies are slight.

It is of interest to note some results of a study by Codippily (1979), also relating to Sri Lanka. He used a simple Static Linear programming model to distribute a fixed amount of investible resources among sectors and he examined the differences in the patterns of allocation under different objectives. His conclusions are generally validated by the present study and to a certain extent summarise the results of our more complex dynamic model under the differing objectives of total income, poor income and employment. He concludes:

"Whether the objective is one of growth or increasing the income of the poor, the main thrust of development ought to be in agriculture."

Codippily(1979 p.8-19)

".... as far as agricultural development is concerned, there is a great degree of complementarity between the employment objective and growth objective, and in turn with the distribution objective. In other words, agricultural development provides a strong positive linkings between the growth, redistribution and employment objectives."

Codippily(1979 p.8-24)

However, our results suggest an amendment to Codippily's conclusion whereby 'agriculture' ought to be replaced by 'agriculture and agriculture-based light manufacturing industries'.

Notwithstanding the close affinity between the above objectives, there seems to be a substantial trade-off between the total income objective and the objective of maximizing industrial output. Compared with the results of Max Y approach, the maximization of the discounted sum of industrial output (i.e. Max ID approach) results in a 7.92% fall in the discounted sum of total income, while it increases the discounted sum of industrial output by 7.87%. In line with total income, the discounted sum of poor income and total employment also drops by 9.92% and

and 10.10% respectively, while there is no difference in the effect on the balance of payments. Such a substantial trade-off between the objectives of total income and industrial output is to be expected, as the maximization of the total income (and also of income of the poor and total employment) placed a high emphasis on agriculture and agriculture-based light manufacturing industries. Pursuing an objective of maximizing industrial output encourages the economy to develop Modern Industry more intensively which has a relatively high capital-output ratio and low income coefficient, as well as developing Light Manufacturing industries, while reducing the dependency on agriculture. This is revealed in a comparison of the sectoral composition of output under the Max Y and Max ID approaches which are shown in Table 9.3.

As we have seen previously, the objective of maximizing total income places more emphasis on Other Agriculture and Light Manufacturing industries. In contrast, the Max ID objective suggests a reduction in the dependency on Other Agriculture by reducing its share in total output while placing a relatively high emphasis on Light Manufacturing industries. Thus, the share of Other Agriculture drops from 21.97% in 1980 to its lowest level of 17.15% in 1983 although it rises slightly to 18.59% again by 1984. In terms of the discounted sum of output, its share drops to 19.50% compared with 23.05% which resulted under the Max Y approach. The share of Light Manufacturing increases from 19.47% in 1980 to a maximum of 25.33% in 1983. In terms of discounted sum of output, it records a share of 22.67% compared to 21.21% under the Max Y approach. Moreover, the

TABLE 9.3.

S[illegible]ral Composition of Domestic Output under the Individual Optimization of the Objectives of Total Income, Industrial Output and Balance of Payments.

(Percentages)

	1980			1981			1982			1983			1984			In terms of Discounted Sum of Output		
	MaxY	MaxID	Max(-M)	MaxY	MaxID	Max(-M)	MaxY	MaxID	Max(-M)	MaxY	MaxID	Max(-M)	MaxY	MaxID	Max(-M)	MaxY	MaxID	Max(-M)
Tea & Rubber	5.12	5.44	5.36	5.08	5.17	5.10	4.54	4.81	4.55	4.14	4.53	4.43	4.12	4.35	4.41	4.60	4.87	4.77
Other Agriculture	21.28	21.97	22.39	21.73	22.15	21.83	23.85	17.53	24.35	24.54	17.15	23.44	23.74	18.59	22.03	23.05	19.50	22.83
Light Manufacturing	18.87	19.47	19.84	19.63	20.01	19.72	23.16	23.69	24.42	22.82	25.33	22.46	21.44	25.06	21.12	21.21	22.67	21.55
Modern Industry	11.70	12.08	12.31	12.18	12.41	12.23	10.13	15.33	10.14	8.63	14.84	13.07	10.02	13.38	12.62	10.50	13.59	12.05
Mining & Construction	10.49	9.45	10.07	10.94	9.94	10.61	8.73	9.07	7.30	10.63	8.69	7.10	9.99	8.05	8.54	10.15	9.05	8.71
Services	32.54	31.59	30.03	30.44	30.31	30.51	29.59	29.57	29.24	29.24	29.46	29.50	30.69	30.57	31.28	30.49	30.31	30.09
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

present approach suggests the development of Modern Industry so that its share of output will increase as well. In terms of the discounted sum of output, Modern Industry records a share of 13.59% which is 3.09 percentage points higher compared with the results of Max Y approach. Therefore, if it is required to develop an industrial base and reduce the uncertainties associated with agricultural products, then the structure of the economy has to be changed so as to increase the share of manufacturing sectors, reducing that of agriculture. However, this does not mean that the agriculture should be neglected. Development of manufacturing industries includes Light Manufacturing industries as well. Development of Light Manufacturing requires substantial indirect inputs from Other Agriculture and, in turn, Other Agriculture has to meet a substantial consumption demand as well. Therefore, given the limited capacity to import competitive goods, even the Other Agriculture sector should be developed, but the difference is in the degree of emphasis to be placed on it.

There are conflicts between the balance of payments objectives and all other objectives. Compared with the results obtained from all other objectives, minimization of the discounted sum of imports [i.e. Max(-M) approach] results in a 10.72% reduction in the discounted sum of imports.[1)] Compared with the results of Max Y approach, for instance, this improvement in the balance of payments objective is accompanied by 4.33%, 4.64% and 4.49% reductions in the discounted sum of total income, poor income, and total employment respectively; while the discounted sum of

1. This and the following percentages are derived directly from the Pay-off matrix (Table 9.1).

industrial output is actually increased by 1.60%. On the other hand, compared to the results of Max ID approach, Max(-M) approach results in 3.90%, 5.85% and 6.23% increases in the discounted sum of total income, poor income, and total employment while the discounted sum of industrial output is declined by 5.76%. In this sense, the results of Max(-M) approach fall between the results of Max Y and Max ID approaches. Max Y generates the lowest value for industrial output objective while the Max ID provides the lowest value for the total income objective. Max(-M) approach provides intermediate values for both of these objectives but obviously with an improved balance of payment position.

Even the economic strategy suggested by the Max(-M) approach could be interpreted as intermediate to those suggested by Max Y and Max ID approaches. The Max Y approach suggests a high specialisation in Other Agriculture and Light Manufacturing while Max ID approach suggests a rapid development of both industrial sectors thereby reducing the share of agriculture in total output. If we consider these two strategies as extremes, the strategy suggested by the Max(-M) approach is an intermediate one. The intermediate nature of this strategy is revealed in a comparison of the sectoral composition of outputs reported in Table 9.3. For example, in terms of the discounted sum of output, the share of Other Agriculture at 22.83% is lower than the share resulted under Max Y approach but higher than that resulted under Max ID approach. On the other hand, the shares of Light Manufacturing and Modern Industries at 21.55% and 12.05% respectively are higher than those yielded with the Max Y approach but lower than those resulted under the Max ID approach. In this sense, Max(-M) approach suggests an intermediate strategy in which both agriculture and industries are developed simultaneously without specializing heavily on either agriculture or industries. It still suggests that Other Agriculture and Light Manufacturing industries be developed at a higher rate, as evidenced by the increased share of output of these two sectors in the latter years compared to the initial year (1980); but the rate of development is lower than that suggested under Max Y approach. In terms of the discounted sum of output, the share of output of Other Agriculture, Modern Industry and Services are very close to those in the initial year while the share of Light Manufacturing is 1.71 percentage points higher. Thus the strategy of development suggested by Max(-M) approach is to develop all the above sectors simultaneously while placing a little more emphasis on Light Manufacturing industries.

9.2 A Unified Solution: Hierarchical Programming Method.

Having evaluated all the objectives individually and examined the strategies of development suggested by each of the objectives, it now remains to explore a unified solution and thereby a single strategy of development in which all the objectives are taken into account. For this purpose, two procedures discussed in Chapter 8 are examined. In the present section, the hierarchical optimization procedure is applied while as an alternative, the Interactive programming method is used in the next section. In view of the close uniformity of the results of the Max Y , Max YP and Max EMP approaches, only the total income is considered as an independent objective. Therefore, the 5 objectives are reduced to only three objectives, i.e. total income, industrial output and balance of payments deficit, and these are incorporated in the application of Hierarchical and Interactive programming methods.

Given a set of conflicting objectives, a unified solution can be obtained using the Hierarchical programming method if the objectives can be ranked according to their importance. This requires some information input by the Decision Maker. For the purpose of illustration, we have assumed that the community is prepared to give the first priority to the total income second to the industrial output and third to the balance of payment objective. Given this ranking order of objectives, the first stage of the optimization procedure is to maximize the discounted sum of total income which we have already done. The second stage is to maximize the second most important objective, i.e. industrial output subject to an added constraint that the discounted sum of total income should not be less than a specified proportion of the value obtained in the first stage. i.e.

$$\text{Max ID} = \sum_{t=1}^{5} (X_{3t} + X_{4t})/(1+w)^{t-1}$$

s.t.

$$\underline{X} \in S$$

and $$\sum_{t=1}^{5} [V'X(t)+VG(t)]/(1+w)^{t-1} \geq \beta_1 \, 78846$$

where β_1 specifies the tolerance limit. The upper limit of β_1 is of course unity. The lower limit of β_1 is defined by the ratio between the discounted sums of total income obtained under the Max ID approach $\{w_1(\mathring{\underline{X}}_2)\}$ and the Max Y approach $\{w_1(\mathring{\underline{X}}_1)\}$. i.e.

$$\frac{w_1(\mathring{\underline{X}}_2)}{w_1(\mathring{\underline{X}}_1)} = \frac{72599}{78846} = 0.92077$$

If β_1 is specified at unity, then the second stage result would give exactly the same discounted sum of industrial output resulted under Max Y approach. Similarly, if β_1 is specified at 0.92077 it would result in the same discounted sum of industrial output which was obtained under Max ID approach. Therefore an improvement in the discounted sum of industrial output has to be obtained by trading off some of discounted sum of incomes. In this respect β_1 has to be specified somewhere within this range. In our application β_1 was arbitrarily specified at the mid point of the range at 0.96. However, the results we eventually obtain will obviously depend on the specified value of β_1 . This second stage of the optimization procedure results in a discounted sum of industrial output of Rs. 38216 mn. Now the third stage is to minimize the discounted sum of total imports subject to the added constraints on discounted sum of total income and industrial output as follows:

$$\text{Max}(-M) = -\sum_{t=1}^{5} [i'M''(t) + m'X(t)]/(1+w)^{t-1}$$

$$\text{s.t.} \quad \underline{X} \in S$$

and

$$\sum_{t=1}^{5} [V'X(t)+VG(t)]/(1+w)^{t-1} \geq 75692$$

$$\sum_{t=1}^{5} (X_{3t} + X_{4t})/(1+w)^{t-1} \geq \beta_2 \; 38216 \quad .$$

Now β_2 has to be specified of which, again, the upper limit is unity. The individual optimization of the balance of payments objective resulted in a Rs. 36458 mn. of discounted sum of industrial output. If we could consider this as the minimum of level of the discounted sum of industrial output which may result in the present stage, then the lower limit for β_2 would be 36458 divided by 38216 which is 0.95. However, the present stage contains a constraint on the discounted sum of total income as well. Therefore Rs.36458 mn. might not be the lowest possible value of industrial output objective at this stage. However, the worst outcome for the industrial output objective cannot be less than Rs. 35885 which resulted under Max Y approach. Thus, if we use this outcome, the lowest value for β_2 would be 0.93900. Thus β_2 should be specified within the range of 1 to 0.939. As before, β_2 was arbitrarily chosen within the permissible range at 0.96. This resulted in a discounted sum of imports of Rs.18604 mn. The final results of the Hierarchical optimization procedure are reported in Table 9.4.

TABLE 9.4.

Hierarchical Programming Results with $\beta_1 = \beta_2 = 0.96$

	Ideal Solution ($\overset{*}{\underline{w}}$) (1)	Minimum attainable Value ($\underline{\bar{w}}$) (2)	Hierarchical Programming Results (3)	Deviation of (3) from Ideal Solution (4)
Discounted sum of				
Total Income (Rs.mn)	78846	72599	75692	4.00%
Industrial Output (Rs. mn)	38687	35885	36687	5.17%
Imports (Rs. mn)	18586	20818	18604	0.10%

As can be seen from the above table, compared to the ideal solution, the final results represent 4.00% reduction in the discounted sum of total income, 5.17% reduction in the discounted sum of industrial output and only 0.10% increase in the discounted sum of imports. Therefore, even though the lowest rank was initially given to the balance of payments objective, judging in terms of the percentage deviation from the ideal solution, the discounted sum of imports has deviated least, that is it seems to be ranked highest on the outcome. Even the economic strategy suggested by the final results is similar to that suggested by the Max(-M) approach. This can be seen in Table 9.5 where sectoral composition of output under the three stages of Hierarchical programming procedure is shown.

TABLE 9.4.

Hierarchical Programming Results with $\beta_1 = \beta_2 = 0.96$

	Ideal Solution ($\overset{*}{\underline{w}}$) (1)	Minimum attainable Value ($\bar{\underline{w}}$) (2)	Hierarchical Programming Results (3)	Deviation of (3) from Ideal Solution (4)
Discounted sum of				
Total Income (Rs.mn)	78846	72599	75692	4.00%
Industrial Output (Rs. mn)	38687	35885	36687	5.17%
Imports (Rs. mn)	18586	20818	18604	0.10%

As can be seen from the above table, compared to the ideal solution, the final results represent 4.00% reduction in the discounted sum of total income, 5.17% reduction in the discounted sum of industrial output and only 0.10% increase in the discounted sum of imports. Therefore, even though the lowest rank was initially given to the balance of payments objective, judging in terms of the percentage deviation from the ideal solution, the discounted sum of imports has deviated least, that is it seems to be ranked highest on the outcome. Even the economic strategy suggested by the final results is similar to that suggested by the Max(-M) approach. This can be seen in Table 9.5 where sectoral composition of output under the three stages of Hierarchical programming procedure is shown.

TABLE 9.5.

Sectoral Composition of Domestic Output at each stage of the Hierarchical Programming with $\beta_1 = \beta_2 = 0.96$.

(Percentage)

	1980			1981			1982			1983			1984			In terms of Discounted Sum of Output		
	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage
Tea & Rubber	5.12	5.20	5.36	5.08	5.12	5.08	4.54	4.52	4.56	4.14	4.40	4.39	4.12	4.22	4.37	4.60	4.69	4.75
Other Agriculture	21.28	21.68	22.39	21.73	21.91	21.72	23.85	22.89	24.16	24.54	21.09	23.45	23.74	18.98	22.14	23.05	21.33	22.80
Light Manufacturing	18.87	19.21	19.85	19.63	19.78	19.61	23.16	24.36	23.94	22.82	23.67	22.59	21.44	26.46	21.20	21.21	22.70	21.47
Modern Industry	11.70	11.92	12.31	12.18	12.27	12.17	10.13	10.08	10.16	8.63	12.78	13.33	10.02	12.67	13.15	10.50	11.92	12.20
Mining & Construction	10.49	9.76	10.06	10.94	10.42	10.94	8.73	8.95	7.83	10.63	8.50	6.82	9.99	7.54	8.03	10.15	9.04	8.72
Services	32.54	32.23	30.03	30.44	30.50	30.48	29.59	29.20	29.35	29.24	29.56	29.42	30.69	30.13	31.11	30.49	30.32	30.06
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The first stage results are the results of the Max Y approach. In the second stage, where the discounted sum of industrial output was maximized subject to the constraint on the discounted sum of total income, the sectoral composition of output appears to be between those under the Max Y and Max ID approahces, in most of the years for most of the sectors.[1] For the second stage, in terms of the discounted sum of output, the shares of Tea & Rubber, Other Agriculture and Modern Industry lie between those under the Max Y and Max ID approaches, while for the three other sectors, the shares are more or less the same as those recorded under Max ID approach. Even for the latter three sectors, these shares would have been between those generated under the Max Y and Max ID approach if β_1 was higher than 0.96. The sectoral composition of output in the final stage is similar to those recorded under Max(-M) approach, throughout the planning period. The differences are only marginal. Therefore, given the specific ranking of the objectives and the particular values of β parameters, the strategy of development suggested by the Hierarchical programming approach is similar to that suggested by the Max(-M) approach. The important point to be noted, however, is that these results are likely to entirely depend upon the given rankings of the objectives and specified values of β parameters. This issue of the sensitivity of the results will be considered next.

The fact that the results will depend on the rank order of the objectives is fairly obvious. However, as was noted earlier, it is quite possible that the final results may represent a different ranking of objectives (in terms of the relative deviations from the ideal solution)

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1. The sectoral compositions of output under Max Y, Max ID and Max(-M) approaches are shown in Table 9.3.

from those initially specified. This result might have arisen through the arbitrary specification of β parameter. Therefore, sensitivity of the results for an alternative set of β parameters were also examined, where both β_1 and β_2 are fixed at 0.98.

In this case the second stage results yield a discounted sum of industrial output of Rs. 37564 mn which is 2.90% lower compared with the ideal solution, while the discounted sum of total imports remains at a value of Rs. 20818 mn. The final stage results reduce the discounted sum of total imports by 11.11% but it is still 4.34% higher than the ideal solution. In the final stage, the constraint on the discounted sum of industrial output became non-binding thereby indicating that in the present case the lower limit of β_2 is 0.98107 which is slightly higher than our specified value of 0.98. The final results are summarised in Table 9.6.

TABLE 9.6.

Hierarchical Programming results with $\beta_1 = \beta_2 = 0.98$

	Ideal Solution ($\overset{*}{w}$) (1)	Minimum attainable value (w) (2)	Hierarchical Programming Results (3)	Deviation of (3) from Ideal Solution (4)
Discounted Sum of				
Total Income (Rs.mn)	78846	72599	77269	2.00%
Industrial Output (Rs.mn)	38687	35885	36853	4.74%
Imports (Rs.mn)	18586	20818	19393	4.34%

In terms of the relative deviation from the ideal solution, the present results also represent a different ranking of objectives from those initially specified. However, by experimenting with different values of β parameters, it might be possible to obtain the same ranking of objectives even in terms of the relative deviation from the ideal solution.

Compared with the results with $\beta_1 = \beta_2 = 0.96$ which implied that a similar strategy to that suggested by the optimization of balance of payment objective be followed, the present solution suggests a slightly different strategy as indicated by the sectoral composition reported in Table 9.7.

In this case the final results place a little more emphasis on Other Agriculture and Light Manufacturing and a little less on Modern Industry. In terms of the discounted sum of output, the shares of Other Agriculture and Light Manufacturing represents increases of 0.12 and 0.19 percentage points while the share of Modern Industry is reduced by 0.73 percentage points. Services also show a 0.40 percentage point increase in its share of output. Compared with the total income objective balance of payments objective suggests that Modern Industry be developed at a high rate. When it is required to place priority on total income, development of Modern Industry has to be curtailed to promote developments in those sectors which provide relatively more incomes.

The dependency of the results on β parameters is highlighted by the differences in the results under the two different sets of β parameters. To make the things more complex, there is more than one way

TABLE 9.7.

Sectoral Composition of Domestic Output at each Stage of the Hierarchical Programming with $\beta_1 = \beta_2 = 0.98$.

(Percentages)

	1980			1981			1982			1983			1984			In terms of Discounted Sum of Output		
	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage	1st Stage	2nd Stage	3rd Stage
Tea & Rubber	5.12	5.12	5.17	5.08	5.08	5.07	4.54	4.59	4.56	4.14	4.27	4.31	4.12	4.12	4.22	4.60	4.63	4.67
Other Agriculture	21.28	21.28	21.52	21.73	21.72	21.70	23.85	22.53	23.85	24.54	24.04	24.10	23.74	21.86	23.39	23.05	22.30	22.92
Light Manufacturing	18.87	18.87	19.07	19.63	19.62	19.60	23.16	24.36	23.16	22.82	24.10	24.11	21.44	26.08	22.30	21.21	22.61	21.66
Modern Industry	11.70	11.70	11.83	12.18	12.17	12.16	10.13	10.24	10.17	8.63	9.85	10.62	10.02	10.63	12.64	10.50	10.91	11.47
Mining & Construction	10.49	10.49	10.06	10.94	10.83	10.92	8.73	8.93	8.78	10.63	8.34	7.53	9.99	7.20	6.82	10.15	9.15	8.82
Services	32.54	32.54	32.35	30.44	30.58	30.54	29.59	29.35	29.47	29.24	29.40	29.33	30.69	30.11	30.63	30.49	30.40	30.46
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

of defining β parameters. The β's were previously defined as total trade-off coefficients which indicate the average trade off of an objective with respect to all other objectives and these were defined on the sub-optima generated during the programme. As an alternative the same kind of coefficients could be defined on the individual original optima of the objectives rather than the sub optima. In addition, for each objective a different tolerance limit could be specified at each stage of the programme. These partial trade-off coefficients also can be defined either with respect to the successive values of the objectives resulting from the foregoing stages, or with respect to the given individual original optima [c.f. Delft and Nijkamp, (1976)] . Therefore, a certain amount of arbitrariness is introduced into the programming procedure in selecting which definition of β to be adopted and deciding exact values for β parameters.

As we have reported in Chapter 8, Delft and Nijkamp (1976), suggest that to overcome the above problem the sum of relative discrepancies between the original optimum value and actual unknown value of the objectives be minimised subject to a hierarchical ranking of these relative discrepancies. However, even though the idea has some appeal, there are problems with implementing it within a linear programme. Strict inequality (i.e. $<$ or $>$) constraints cannot be incorporated with the linear programming technique, hence the present method can be applied only for weak ordering (i.e. $\leq$ or $\geq$) of the objectives. But when it is attempted to minimize the sum of relative discrepancies subject to weak ranking of successive discrepancies, it is very likely to end up with all relative discrepancies being equal. This is precisely what happened, in our experiment with this method. It ended up in a solution which represents 3.44% deviation from the ideal solution with respect to each of the objectives. It would be possible to obtain hierarchical ranking of relative discrepancies by minimizing the weighted sum of relative discrepancies, but if we attempt to do that we are back in the original problem of specifying weights on the objectives.

9.3 A Unified Solution: Interactive Programming Method.

The previous section presented the results of the application of Hierarchical programming method in economy-wide planning and also identified the major weaknesses of that method. As an alternative, the present section demonstrates the applicability of an Interactive Programming method. The particular method is the Interactive programming with imposed side conditions; of which a detailed exposition was presented in Chapter 8 (see §8.8.2). In order to apply this method it is required to obtain a provisional solution for the multiple objective problem. A concept of compromise solution[1] is employed in this respect. The present application obtained a provisional solution which is optimal with respect to a set of weights which are defined according to an equal evaluation of all extreme solutions of the Pay-off matrix. As we have shown in Chapter 8, this results in the following vector of weights,

$$\underline{\lambda} = \frac{(P')^{-1} i}{i'(P')^{-1} i}$$

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1. For details see section 8.7 of Chapter 8.

and the compromise solution is obtained by solving the following problem,

$$\text{Max } W = \underline{\lambda}\ \underline{w}(\underline{x})$$

$$\text{s.t.} \quad \underline{x} \in S$$

where $\underline{w}(\underline{x})$ is the vector of objectives and S defines the feasible region.

Table 9.8 gives the details of the interactive procedure, step by step. For each step, it gives the transpose of the pay off matrix, the compromise solution and respective weights. Percentage deviations from the ideal solution are also reported for comparison.

Having presented a compromise solution at the first step, the decision maker (DM) should now be asked which of the objectives in the compromise solution has the most unsatisfactory performance.

As can be seen from Table 9.8, the compromise solution at the step 1 represents a 2.19% reduction in the discounted sum of total income, 3.35% reduction in the discounted sum of industrial output and 6.60% increase in the discounted sum of imports compared to the ideal solution. Considering these percentage deviations, we assume that our hypothetical DM would not be satisfied with the level of performance in the balance of payments objective. Therefore, in the second step, following constraint is added to the basic model.

$$\text{a.} \quad \sum_{t=1}^{5} [i'M''(t) + m'X(t)]/(1+w)^{t-1} \le 19812 \quad .$$

TABLE 9.8.

Interactive Programming Results.

Step	Procedure	Outcome of Objectives			Weights		
		Y	ID	-M	Y	ID	-M
1	Max Y	78846	35885	-20818	1.0	0	0
	Max ID	72599	38687	-20818	0	1.0	0
	Max(-M)	75430	36458	-18586	0	0	1.0
	Compromise Solution	77116	37391	-19812	0.2388045	0.5324089	0.2287866
	Deviation from the Ideal Solution(%)	2.19	3.35	6.60			
2	Max Y	77868	36772	-19812	0.46112	0	0.53888
	Max ID	72364	38340	-19812	0	0.59238	0.40762
	Max(-M)	75430	36458	-18586	0	0	1.0
	Compromise Solution	75283	37631	-19209	0.1351658	0.4744970	0.3903372
	Deviation from the Ideal Solution(%)	4.52	2.73	3.35			
3	Max Y	77868	36772	-19812	0.46112	0	0.53888
	Max ID	75283	37924	-19812	0.10706	0.64038	0.25256
	Max(-M)	75430	36458	-18586	0	0	1.0
	Compromise Solution	76084	37109	-18965	0.1721964	0.3864040	0.4413996
	Deviation from the Ideal Solution(%)	3.50	4.08	2.04			
4	Max Y	77868	36772	-19812	0.46112	0	0.53888
	Max ID	76084	37719	-19812	0.13038	0.59534	0.27428
	Max(-M)	76084	36654	-18719	0.35083	0	0.64917
	Compromise Solution	76390	37357	-19342	0.2119	0.399155	0.388945
	Deviation from the Ideal Solution(%)	3.11	3.44	4.07			

This requires that the discounted sum of imports should not exceed Rs. 19812 mn which is the value yielded in the first compromise solution.

In the second step, both income and industrial output objectives are maximized subject to this additional constraint. This results in a new Pay-off matrix and, accordingly, following the same method as before, the second compromise solution is obtained. This solution should be presented to the DM and be asked the same question as before.

As expected, the second compromise solution resulted in an improvement of the balance of payment objective; compared to 6.60% deviation in the first compromise solution, the present solution represents only 3.35% deviation from the ideal solution (i.e. $\underline{w}^*$ in the step 1). It also improves the level of performance of the industrial output objective; compared to 3.35% deviation in the first compromise solution, the present solution represents only 2.73% deviation from the ideal solution. This happens despite the fact that the second compromise solution gives lower weights to the industrial output objective, compared with the first. This is because of the fact that in the present solution, the improvement in the balance of payments objective is obtained by increasing the domestic output of Modern Industry which is promoted under the industrial output objective, for which the present solution gives the highest compromise weight. The improvements in both the balance of payment and industrial output objectives are achieved at the expense of the level of performance of the total income objective. For this objective, the present solution represents a 4.52% deviation from the ideal solution compared to 2.19%

in the first compromise solution. Therefore, with respect to the second compromise solution, it is assumed that the DM would not be satisfied with the level of performance in the total income objective. Therefore, in the third step, following constraint also is added to the basic model.

$$\text{b.} \quad \sum_{t=1}^{5} [V'X(t) + VG(t)]/(1+w)^{t-1} \geq 75283 \quad .$$

This requires that the discounted sum of total income should not be less than Rs. 75283 mn, this being the value which resulted from the second compromise solution.

In the second step, the maximization of industrial output objective resulted in a discounted sum of total income which is lower than Rs. 75283 mn. Therefore, in the third step, the industrial output objective has to be maximised subject to both of the above constraints a and b, while the second step results of Max Y and Max(-M) remain unchanged. Now using the Pay off matrix at the third step, new compromise weights are calculated and accordingly a third compromise solution is obtained. The third step gives relatively higher weights to the total income objective compared with the second step, yet the balance of payment objective receives the highest weight among all the objectives. Accordingly, the level of performance of the balance of payment objective improves still further, whereby the deviation from the ideal solution is reduced to 2.04% while the deviation for the industrial output objective is increased to 4.08%. The main aim at this step of improving the level of performance of income objective is certainly achieved, but not at a substantial rate. Thus, compared with a 4.52% deviation in the second compromise solution in the present solution the deviation from the ideal solution drops to 3.50%. Therefore, with respect to the third compromise solution, it is assumed that the DM would still not be satisfied with the level of performance of the total income objective. Accordingly, in the fourth step, the constraint b is revised as follows, and added to the basic model.

$$b' \qquad \sum_{t=1}^{5} [V'X(t) + VG(t)]/(1+w)^{t-1} \geq 76084$$

where the right hand side figure of 76084 is the discounted sum of total income which resulted from the third compromise solution.

Subject to these two additional constraints (i.e. a and b'), both industrial output and balance of payment objectives are maximized at the fourth step and accordingly the fourth compromise solution is obtained. This compromise solution improves the level of performance of both total income and industrial output objectives, increasing the discounted sum of imports, compared to the third compromise solution. The present solution represents 3.11% and 3.44% reductions in the discounted sum of total income and industrial output, and 4.07% increase in the discounted sum of imports compared with the ideal solution.

At this step, we assume that the DM would be satisfied with the fourth compromise solution and therefore the interactive procedure is terminated.

In Table 9.8, the weights assigned to each of the objectives in the compromise solutions and the implicit weights in the other alternative solutions are also reported. As the objectives are evaluated individually at the first step, the implicit weights are obvious. The objective considered as the maximand receives the weight of unity while others carry no weights at all. In all the other steps, the implicit weights are derived using the shadow prices of the additional constraints (a) and (b) or (b'). For example, in the second step, the constraint on the discounted sum of imports yielded a shadow price of 1.16863 when discounted sum of total income is maximised. This indicates that the discounted sum of total income can be increased by 1.16863 by increasing the discounted sum of imports by one unit over the level of Rs. 19812 mn. This implies that we have assigned a weight of 1.16863 to the balance of payments objective while the maximand (i.e. total income objective) has the weight of unity. Therefore, by normalization this implies the weight of 0.46112 to the income objective and 0.53888 to the balance of payments objective.

The most important feature of this interactive method is that it does not require the DM to articulate his preferences precisely. The importance of this fact is clear when this method is compared with the Hierarchical method. As we have seen in the previous section, to apply Hierarchical method, the DM is required to rank the objectives according to their importance, but that alone is not sufficient. He has to specify values for parameters β_1 and β_2 ; we have seen the difficulties in specifying β's and the sensitivity of results to the changes in β's.

Moreover, a specification of β may result in a final outcome which may not be consistent with the original rank order of the objectives.

To apply the interactive method, the only thing the DM has to do is to indicate the objective which has the least satisfactory performance in the compromise solution, at each step. Therefore, he does not have to specify exact weights, tolerance areas or even his ranking of the objectives. Yet, this interactive procedure can lead to results which are consistent with his (unexpressed) preference and the weight on the objectives can be derived within the procedure itself.

The second importance of the interactive procedure is that it generates a manageable sub-set of efficient solutions. As we have discussed in Chapter 8, a multiple objective problem contains very large set of efficient solutions and if such a large set of solutions are presented to the DM, it would be very difficult for him to digest all the information and make a sound decision. On the other hand, once the rank order and β parameters are specified, the Hierarchical method would present him with a single solution and therefore his decision may not be well-informed. Without falling into either of these two extreme categories, the interactive procedure presents the DM with a manageable number of efficient solutions. For example, Table 9.8 gives 16 efficient solutions. Therefore, it generates a sufficient amount of information which are useful in decision-making. Moreover, the DM closely participates in the interactive procedure and therefore when confronted with the feasibilities he could judge his (unexpressed) preferences and if necessary modify them.

Another important aspect of the interactive procedure is the convergence property. Due to this property, the distance between maximum and minimum attainable values of the objectives diminishes as we proceed into further and further steps. For example, the distances between maximum and minimum attainable values in the first and fourth steps are given in Table 9.9 below.

TABLE 9.9.

Distances between Maximum and Minimum Attainable Values of the Objectives.

	1^{st} step	4^{th} step	% reduction
Discounted sum of			
Total Income (Rs.mn)	6247	1784	71.44
Industrial Output (Rs.mn)	2802	1065	61.99
Imports (Rs. mn)	2232	1093	51.03

Therefore, after a certain number of steps, so little room for improvement of the objectives is left that a further search for a better compromise solution becomes pointless.

Finally, before the end of this section, it would be useful to examine the strategy of economic development suggested by the final compromise solution of the Interactive Programming procedure, and compared it with the strategies suggested by the individual optimization of the objectives.

For this purpose, the sectoral composition of the output suggested by the 4th compromise solution is reported in Table 9.10.

This solution seems to be suggesting simultaneous development of all the sectors except Tea & Rubber and Mining & Construction, without concentrating highly either on agriculture or manufacturing industries. Starting from 22.24% in the initial year, the share of Other Agriculture reaches the maximum of 24.12% in 1983, but drops to 22.60% in 1984. In terms of discounted sum of output its share of 22.64% is only slightly higher than the initial share. Light Manufacturing increases its share from 19.71% in 1980 to 24.35% in 1982 and declines gradually to 23.66% by 1984. In terms of discounted sum of output, its share of 22.32% is 2.61 percentage points higher than the initial share. Modern Industry reduces its share from 12.23% in 1980 to 10.24% in 1982 but increases to 12.51% by 1984. In terms of discounted sum of output, its share of 11.46% is only 0.77 percentage points lower than the initial share. Services maintain its share more or less at the initial level throughout the planning period. Therefore, the present solution, taking all the three objectives into account, suggests that all the sectors other than Tea & Rubber and Mining & Construction, should be developed simultaneously, but placing more emphasis on Light Manufacturing and a little less on Modern Industry.

Compared with the economic strategies suggested by the individual optimization of each of the objectives,[1] the present solution suggests

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1. See Section 9.1 and compare Table 9.10 with Table 9.3.

TABLE 9.10.

Sectoral Composition of Domestic Output in the Fourth Compromise Solution.

(Percentages)

	1980	1981	1982	1983	1984	In terms of Discounted Sum of Output
Tea & Rubber	5.33	5.08	4.58	4.30	4.18	4.69
Other Agriculture	22.24	21.72	22.48	24.12	22.60	22.64
Light Manufacturing	19.71	19.62	24.35	24.08	23.66	22.32
Modern Industry	12.23	12.17	10.24	10.26	12.51	11.46
Mining & Construction	10.50	10.83	9.01	7.85	6.67	8.96
Services	29.99	30.58	29.34	29.39	30.38	29.93
Total	100.00	100.00	100.00	100.00	100.00	100.00

neither to specialise in Other Agriculture to the extent indicated by Max Y approach, nor to reduce the dependency on Other Agriculture to the extent suggested by Max ID approach. Similarly, it does not place such a high degree of emphasis on manufacturing industries as is suggested by Max ID approach, but it does place more emphasis than that suggested by Max Y approach. Therefore, specialising heavily in agriculture or manufacturing industry is not an optimal strategy when all the objectives are taken into account, nevertheless, a higher emphasis should be placed in Light Manufacturing and a lower emphasis on Modern Industry. Tea & Rubber should be developed, but its rate of growth is constrained by exogenously specified demand for exports and therefore its share in total output is reduced continuously. Mining & Construction is also developed at a lower rate than other sectors. The demand for the output of this sector is limited because it is mainly an indirect demand to provide investment goods.

9.4 A Note on the Distributional Implications.

In our discussion of distributional implications of the results in Chapter 7, we pointed out the positive link between income generating activities of the poor and the rich households and the inability of production planning within Sri Lankan context to change the income shares substantially. As further supporting evidence on this issue, the share of disposable income of the poor households in total income under the individual optimization of each of the five objectives and under the final results of Hierarchical and Interactive programming are reported in Table 9.11.

TABLE 9.11.

Income Shares of the Poor Households in the Different Approaches of Multiple Objective Programming (Pre-plan share = 48.21)

(Percentages)

	1980	1981	1982	1983	1984	In terms of Discounted Sum of Incomes
Max Y	48.16	48.41	49.47	49.81	49.21	49.01
Max YP	48.26	48.35	49.43	50.32	49.86	49.25
Max EMP	48.25	48.36	49.44	50.31	49.88	49.25
Max ID	48.45	48.50	47.42	47.46	47.82	47.95
Max (-M)	48.61	48.42	49.71	49.05	48.42	48.85
Hierarchical Programming						
(i) with $\beta_1 = \beta_2 = 0.96$	48.61	48.40	49.61	49.06	48.44	48.83
(ii) with $\beta_1 = \beta_2 = 0.98$	48.23	48.39	49.47	49.58	48.96	48.92
Minimization of relative deviations from the Ideal solution	48.58	48.39	49.30	49.50	48.72	48.90
Fourth Compromise Solution	48.58	48.39	49.22	49.60	48.90	48.94

Both the Max YP and Max EMP approaches provide more or less the same share of income for the poor. In terms of discounted sum of income, these two approahces provide the highest share of 49.25% for the poor, but it is only 1.04 percentage points higher than the preplan share. Max Y approach also provides an income share of 49.01% (in terms of discounted sum of income) for the poor, which is only 0.24 percentage points less than that recorded by the Max YP and Max EMP approahces. Only the Max ID approach reduces the income share of the poor, but the reduction is only marginal. In terms of discounted sum of income, Max ID approach, reduces the income share of the poor only by 0.26 percentage points compared to the preplan share. All the other approaches increase the income share of the poor, but the increases are only marginal. Therefore, these results confirm the earlier conclusions regarding the inability of production planning to change the income shares substantially and the positive link between overall growth and distribution.

CHAPTER 10.

Conclusions.

The main objectives of this study have been to examine the relative importance of domestic savings and foreign exchange and also to highlight the distributional implications of development along an optimal development path for Sri Lanka. In addition, an attempt has been made to examine the use of formal techniques for planning the sectoral and temporal allocation of resources for economic development through an investigation of the feasibility of Sri Lanka's Public Investment Programme 1980-1984. A Multisectoral Intertemporal Optimization model was presented and experiments were carried out on the model to accomplish these objectives. Some multiple objectives of economic development were identified and recent developments in Multiple Objective Decision methods were applied in arriving at a solution to the multiple objective problem in economy-wide development planning. The present chapter concludes the study by highlighting the main conclusions with respect to the main objectives of the study. It also provides some suggestions for further extensions of this study.

10.1 Public Investment Programme 1980-1984.

In the application of the model for Sri Lanka, targets for terminal capacity requirements and all other exogenous values were specified in such a way that they are consistent with the expectations of the public investment programme (PIP). Therefore, the model solutions can be used to examine the implications during the planning period (1980-1984) of the targets implicit in the PIP. If a solution cannot be found with the targets, then there is a technical infeasibility with the assumed parameters and constraints. However, the results can of course be changed by modifying the assumptions. Therefore, as Eckaus and Parikh (1968 p.197) pointed out, the issue of feasibility finally depends on a judgement as to whether the parameters and allocations necessary for success will in fact be achieved.

It is understood that the PIP has been prepared on a judgemental and informal basis. Therefore it does not spell out any of the parameters required to be specified in estimating production, income and demand. These have been estimated using the other sources of data. Therefore, one might argue that our results cannot be used to examine the PIP as the PIP did not assume the relationships and parameter values we specified in the model. However, one purpose of the present study has been to examine the feasibility and implicationsof a programme which was prepared on an informal basis by using a formal model of the economy and which explicitly takes into account the structure of the economy, production and behavioural relationships and possible constraints for development. Such an attempt could shed some light on the importance of using a formal planning technique.

The results derived from the present model indicate that the PIP targets are technically infeasible, i.e. no allocation of resources exists that could achieve the targets. In fact, in the model specification and application investment gestation lags were reduced from three years to two years in order to make the model less restrictive. In a preliminary application, it was found that a lack of initial capital and capital in process in Modern Industry highly constrains the feasibility of a solution. Therefore, in the final application, in estimating initial capital and capital in process it was assumed that, relative to Light Manufacturing, Modern Industry has grown at a high rate from 1970 to 1979. Yet the results indicated that the targets are infeasible. An optimal solution was obtained by reducing the target levels of public overhead investments to 37.18% of the total in each year. It was also found that 100% of planned public overhead investment could only be incorporated with reduced levels of targets for terminal capacities.

We believe that these results suggest reasonable doubts about the feasibility of the PIP targets. In fact, it appears that even the Sri Lankan planners have latterly realised the operational infeasibility of the programme as they have scaled down some of the public overhead investment plans late in 1980.[1)] Throughout the study we highlighted the implications of public overhead investment and found that it significantly reduces the total income that could be generated within the planning period and from this loss of income the poor suffer more than the rich. Of course it is for political authorities to decide whether such a reduction in income within the planning period is justified. However, given the infeasibility of the PIP targets and the implications of public overhead investment for the planning period, it might be well worth considering rephasing the public overhead investment over a longer horizon since it imposes a heavy burden upon the available resources.

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1. Ministry of Finance and Planning (1981 p.3).

The model solutions do not indicate how the economy would perform if infeasible targets are pursued. Heavy pressure on available resources may create high inflation and the economy may end up in a foreign exchange crisis requiring more foreign financial assistance than planned. In this respect, it is worth noting the comments of some journalists that the government has run too fast and the economy has become 'overheated'.[1] This tends to confirm the views expressed here.

10.2 Domestic Savings and Foreign Exchange.

The model specified in the study is a Two Gap model of Chenery-Bruno (1962) type as it incorporates both savings and foreign exchange constraints simultaneously. The two-gap approach has been partially an attempt to put forward a rationale for external resource transfers to developing countries indicating that these countries cannot achieve a high rate of growth either because of a lack of domestic resources to finance investment or because of a lack of foreign exchange to finance import requirements. Within this framework this study has attempted to identify dominating constraints for further economic development in Sri Lanka. All the solutions generated under the different assumptions suggested the existence of a foreign exchange constraint. However, not all the solutions suggested the existence of a savings constraint in each year.

Only in a few experiments where public overhead investment was incorporated either partially or fully did both the savings and foreign exchange constraints become binding throughout the planning period. In

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1. e.g. See 'Sri Lanka: Island in a hurry. A survey' in The Economist, June 13, 1981, Vol. 279. after p.52.

all the other experiments it was the foreign exchange constraint which became binding in almost all the years. Therefore, as a whole, the study lays claim for the importance of foreign financial assistance. When both the constraints are binding foreign financial assistance is required to supplement domestic savings as well as to finance import requirements. If no foreign financial assistance is forthcoming, economic growth is not sustainable even without incurring any expenditure on public overhead investment.

The model solutions indicated the possibility of generating reasonably high levels of savings as well as overall savings ratios on an optimal path of development, given the savings ratios of the poor and the rich. These high savings were generated mainly by restricting the government current expenditure. The model lets the government revenue grow along with the growth in the economy, but the growth in the current expenditure was restricted to only 5.3%. In addition, with the fixed income coefficients the contribution of the corporate enterprises (i.e. Other Institutions) to overall savings become high as the economy grows. Therefore, as a whole, the model solutions generated a substantial amount of domestic savings and it was found that economic development is not largely restricted by the lack of domestic savings to finance investment. It is mainly the lack of foreign exchange that restrict the further growth in the economy.

In fact most of the solutions suggested the possibility of generating a more than adequate amount of savings exante. As we have shown in Chapter 6, the results shed some light on the possible negative relationship between domestic savings and foreign financial assistance. However, this does not support the view of some economists[1] that foreign financial assistance could retard the development by encouraging recipient countries to save less. When the Trade Gap is dominating, foreign financial assistance which is forthcoming to fill the gap may result in a level of realised domestic savings which is less than the potential level. That does not mean that development is retarded. In fact, foreign financial assistance is needed to break the bottleneck and promote economic development. Therefore, even if there is a negative association, it would still be optimal policy to obtain an increased level of foreign financial assistance since the economy is foreign exchange constrained. The cause for the lower realised domestic savings is the inability to transform all the potential savings into productive investment due to structural rigidities.

The basic notion of a foreign exchange constraint rests on the assumption that for structural reasons the potential savings of a developing country are not a perfect substitute for imports, neither can they be transformed into exports. Some critics[2] find this an extreme assumption and are not prepared to accept the distinction between the domestic resource constraint and the external resource constraint. They believe that domestic resources can be shifted from production for home market to production for exports or to import substitutes. However, the removal of structural rigidities is a long term process which cannot be accomplished within a short period of five years. Therefore the existence of structural rigidities is a reasonable assumption, especially since we

1. e.g. Griffin and Enos (1970).
2. e.g. Bauer and Yamey (1972 p.324).

have incorporated into the model a realistic projection of exports. However, if domestic consumption requires imports of competitive goods then increased domestic savings through reduced consumption would have a favourable effect by reducing the requirements of competitive imports. This was supported in an experiment where the income subsidy on the poor was removed in order to increase overall savings. (Chapter 6, section 6.4.) It indicated that an increased level of savings is useful as it enables the economy to generate a higher level of income within the planning period. As was noted, this increased level of performance was only to the extent that increased savings reduced the requirement of competitive imports.

An increase in the availability of domestic savings would be more useful if the savings ratio of the poor is substantially lower than the ratio estimated for 1970. This was highlighted in the experiment where the savings ratio of the poor was reduced (Chapter 6, section 6.5). If the poor's savings ratio was lower, then the model solution has to generate sufficient level of savings by adjusting the sectoral composition of the output and incomes of the different institutions. Therefore, if the poor's savings ratio is low, an attempt to increase savings is best brought about by increasing this ratio because it provides the necessary flexibility for the model to adjust sectoral composition of output to yield a higher level of overall income.

As a whole this study concludes that given the savings ratio which has been specified for the poor, the rich and other institutions, the importance of additional savings are limited as the development of the economy is highly constrained by the lack of foreign exchange.

The problem of foreign exchange shortages can be overcome by,

1. Obtaining additional foreign financial assistance;

2. promoting exports;

and 3. promoting import substitutions.

Throughout the study the usefulness of foreign financial assistance was highlighted and it was shown that the economy could make productive use of further financial assistance. Export promotion also is useful as it enables the economy to achieve a higher level of consumption and income. However, there is a marked difference between the level of performance that could be achieved by increasing the availability of foreign exchange through foreign financial assistance and through exports. This was revealed in the experiments where the availability of foreign exchange was increased by the same amount through two different routes, i.e. increasing foreign financial assistance and increasing exports of Other Agriculture. It was found that the level of improvement in the consumption and income that could be achieved through increased exports are only partially limited by the lack of resources to finance investment. Compared to this, additional foreign exchange available through foreign financial assistance could make a better contribution to overall consumption and income since it simultaneously alleviates both the savings and foreign exchange constraints and also because the model has complete freedom to use the additional foreign exchange made available through this route. The contribution of increased exports to savings is only indirect and furthermore, increased exports has to come through developing exogenously specified sectors.

However, these results are not being presented as an argument against any attempt to promote exports. A developing country cannot depend on foreign financial assistance forever and export promotion should be the prime policy for the long term solution to the foreign exchange problem. The results merely signify the importance and capability of foreign financial assistance in accelerating economic development.

Within the framework of this model, some implications of an import substitution programme can be evaluated by reducing the non-competitive import coefficients. As has been pointed out (Chapter 6, section 6.8) the coefficients estimated for 1979 are relatively low compared with those estimated for 1970, representing the results of past import substitution programmes. The results obtained under these two different setsof non-competitive import coefficients revealed that the import substitution has been only marginally effective, enabling the economy to achieve slightly higher levels of overall consumption and incomes. It appears that to accelerate economic development, import substitution alone is not a sufficient policy unless perhaps it could be implemented at a very high scale.

As a foreign exchange constrained economy, Sri Lanka should follow policies to increase the availability of foreign exchange. In the present study we did not examine the relative efficacy of an export promotion scheme against an import substitution programme. However, the study suggests that economic development through these strategies could be relatively slow. Therefore, an acceleration of economic growth really requires more foreign financial assistance. However, this should not be interpreted to mean that Sri Lankan policy makers are helpless without foreign financial assistance. While seeking foreign financial assistance to accelerate economic development, domestic economic policies should be designed for the long term solution of the foreign exchange problem.[1)]

10.3 Distributional Implications.

The objective function of the model was particularly designed to incorporate a distributional objective of economic development. A number of solutions were generated under different assumptions and examined to see whether there is a trade off between the objectives of economic growth and income distribution on an optimal path of development. All the solutions examined suggested that development along an optimal path would not worsen the relative income share of the poor. The model's inability to differentiate between the Rawlsian and Utilitarian solutions emphasised that in the context of the Sri Lankan economy, economic growth and distributional objectives are complementary rather than conflicting.

It was also pointed out that, on an optimal path, resources cannot be allocated to obtain a production plan which represents a substantial change in the income shares. Therefore, it was suggested that appropriate instruments to change the disparity in incomes and improve the income share

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1. Nelson (1970) points out the possibility of export expansion through the use of more realistic exchange rate.

of the poor should be fiscal measures and the introduction of different production technologies. The effectiveness of fiscal measures were examined by comparing the solution with and without an income tax on the rich and an income subsidy on the poor (Chapter 7, section 7.5). It was found that the distributional role of these fiscal measures is effective in favour of the poor and does not conflict with economic growth. Despite the recent experience of Sri Lanka as noted in Chapter 1, these conclusions suggest the possibility of achieving economic growth simultaneously with an improvement or at least without worsening the relative income share of the poor.

Experiments with different income coefficients suggested the possibility of changing the income shares by changing production technologies (Chapter 7, section 7.6). Given a specific production technology, the model did not differentiate the Rawlsian solution from the Utilitarian solution. However, when two different technologies are confronted, the Rawlsian and Utilitarian criteria may suggest choosing different technologies. Therefore, in this sense, there could be some, though not necessarily a substantial, conflict between the economic growth and distributional objectives.

10.4 Multiplicity of Objectives.

The study identified several development objectives in addition to the growth in consumption (or income) and its distribution: namely, maximization of employment, industrial output and the minimization of the balance of payments deficit. It was argued that even though some of these objectives may not be independent objectives, they do generally constitute important considerations, and ought therefore to be taken into account. Therefore, these were considered as separate objectives and, given these objectives, the general problem is one of solving a multiple objective set up. Hence the applicability of Multiple Objective Decision methods were demonstrated in arriving at a solution to the multiobjective problem.

An individual evaluation of the objectives of total income, income of the poor and total employment suggested that even though there could be some trade off among these objectives, they are marginal and each of them suggest the same strategy of development, i.e. the main thrust of development should be in Other Agriculture and Light Manufacturing industries. As already mentioned, it suggests the possibility of achieving economic growth without substantially reducing the income of the poor or employment opportunities.

The objective of maximising industrial output suggested reducing the dependency in Other Agriculture and placing a higher degree of emphasis on Light Manufacturing and Modern Industry, while the balance of payments objective suggested an intermediate strategy of development in which it was suggested not to specialise too highly on either agriculture or industry but to simultaneously develop both while placing a little more emphasis on Light Manufacturing industry which is largely based on inputs from Other Agriculture.

In arriving at a unified or compromised strategy of development, it was concluded that the Hierarchical method is not an especially efficient tool. With a pre-specified ranking order of the objectives the possibility was shown that the final results may represent a different ranking order in terms of the relative deviations from the ideal solution. This is due to the arbitrariness introduced into the method by the specification of β parameters (tolerance limits) while the results highly depend on the specification of β. In order to avoid this arbitrariness, the procedure suggested by Delft and Nijkamp (1976) was also considered but it was found that it could not be used to yield a desired ranking order of the objectives within the confines of the linear programming technique.

An interactive method was also applied and it was shown that the particular method chosen provided quite an efficient procedure for arriving at the best compromise solution. This was demonstrated using an empirical strategy involving an hypothetical decision maker and therefore the final solution should not be considered as necessarily the most appropriate solution for Sri Lanka. However, it provides some light as to the type of development strategy that should be followed in the presence of multiple objectives. That particular strategy was not to specialise heavily on either agriculture or industry but to develop both simultaneously.

10.5 Extension of this Study.

Any economic model is a simplification of a real economy and therefore there always exists the possibility of introducing more complexities into the model. However, introducing more complexities is not always desirable as it may tender difficulties in computations and interpretation of the results. As has been seen (Chapter 3) even the introduction of the consumption - income relationships and a savings constraint made the interpretation of the shadow price system more difficult. The introduction of non linear objective function made it difficult to work with more than about six production sectors, given limitations on time and the choice of working within the limits of a linear programming computer package.

However, in a practical planning effort it would be important to disaggregate the production sectors further so that each sector contains a more homogenous set of production activities. With such a sectoral disaggregation, sectoral comparative advantage for exports could be investigated and the implicationsof import substitution could be examined more fruitfully.

With a more disaggregated sectoral classification, it would be more useful to allow for an endogenous determination of exports. The exogenous specification of exports is sufficient for the purpose of testing the implications of an existing plan, yet it is in fact a very rigid treatment. When the exports are exogenously specified, the model does not identify the importance of exportable goods producing sectors as foreign exchange earners. In the foreign exchange constraint exports appear only as a total for all the sectors, thus such a treatment does not identify the individual sectors where exports are produced. Therefore, it would be more meaningful at least to specify lower and upper ceilings for each sector's exports, rather than treating levels of exports completely exogenously. It would provide at least a crude attempt to introduce the rigidities and non linearities in export-producing sectors. Lower limits can be used to eliminate sharp unrealistic drops in exports resulting from the specialization implicit in linear models. Upper limits can be used to reflect certain exogenous factors such as non expanding inelastic demand conditions as well as quota and tariff restrictions on imports in the industrialized countries. Though useful, this procedure could not be followed due to data limitations.

The household demand systems for the poor and the rich incorporated in the model reflect unit income elasticity of demand for goods of each sector. This may not be too restrictive in the present study with the broadly defined six sectors. However, an attempt to introduce changing income elasticities with the level of income would be well worthwhile. Such a treatment needs a priori estimation and identification of well fitting demand systems. However, this would make the model more complex, as it involves the specification of non-linear demand systems.

It would also be important to specify the demand for and supply of labour of each skill, rather than specifying an aggregate labour constraint for each year. Even though the aggregate labour constraint is not binding, there may be shortages in particular skills. Labour constraints by type of skills can easily be incorporated if information on each sector's requirements of particular skills and their overall availability are available. If there are shortages in skills it would also be worth considering the modelling of skill formations.

The treatment of capital depreciation can also be improved. Rather than assuming all types of capital depreciate at the same rate, different eliminate sharp unrealistic drops in exports resulting from the specialization implicit in linear models. Upper limits can be used to reflect certain exogenous factors such as non expanding inelastic demand conditions as well as quota and tariff restrictions on imports in the industrialized countries. Though useful, this procedure could not be followed due to data limitations.

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The treatment of capital depreciation can also be improved. Rather than assuming all types of capital depreciate at the same rate, different rates of depreciation could be introduced for different types of capital. Also a separate treatment of restoration of the depreciated capital would be worth attempting.[1)]

As a whole, all the conclusions of the study should be treated with due caution, because of the limitations in the data used. As was noted in Chapter 4, most of the coefficients used were estimated for 1970. There is no information on initial capital and capital in process and therefore they were estimated indirectly using fairly heroic assumptions. Thus, high priority should be given to the estimation of a new data base. This would inevitably involve substantial amounts of work in data collection and compilation.

Finally, the present study examined the binding constraints and sectoral and temporal resource allocations for economic development. However, it did not look into the problem of how to implement a selected programme. Obviously we are not dealing with a centrally planned economy. Therefore, the implementation of a programme highly depends on the incentives provided by the government. In this respect, fiscal and monetary policy instruments play a crucial role. Therefore, the effectiveness of such instruments need to be examined. However, this can not be done within the framework of the present model. Therefore, in complementary to the present study, it would be useful to build a model to simulate the implications of such policy instruments.

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1. The models of Eckaus and Parikh (1968) incorporate such a treatment.

BIBLIOGRAPHY

Adelman, I. and S. Robinson (1978) Income Distribution Policy in Developing Countries: A Case Study of Korea. Oxford University Press, Oxford.

Adelman, I. and F.T. Sparrow (1966) 'Experiments with Linear and Piecewise Linear Dynamic Programming Models' and comments by Karl A. Fox in I. Adelman and E. Thorbecke (eds.) The Theory and Design of Economic Development. John Hopkings University Press, Baltimore, 291-317.

Ahluwalia, M.S. (1974) 'Income Inequality: Some Dimensions of the Problem' in H.B. Chenery, M.S. Ahluwalia, C.L.G. Bell, J.H. Duloy and R. Jolly, Redistribution with Growth, Oxford University Press, 2-37.

Ahluwalia, M.S., N.G. Carter and H.B. Chenery (1979) 'Growth and Poverty in Developing Countries' Journal of Development Economics. Vol. 6, 299-341.

Bartels, C.P.A. (1975) 'The Effects of Foreign Capital Inflows on Domestic Savings in Developing Countries: A Critical Survey' Zeitschrift Für Nationalökonomie Vol. 35 (1-2), 161-176.

Bauer, P.T. and B.S. Yamey (1972) 'The Economics of Pearson Report', Journal of Development Studies Vol. 8, 319-328.

Beckenbach E. and R. Bellman (1961) An Introduction to Inequalities. Random House, New York.

Beeson, R.M. (1971) Optimization with respect to Multiple Criteria. Ph.D. Thesis, University of South California, Los Angeles.

Beeson, R.M. and W.S. Meisel (1971) 'The Optimization of Complex Systems with respect to Multiple Criteria' in proceedings, Systems, Man and Cybernetics Conference, Institute of Electronic and Electrical Engineers (IEEE), California.

Belenson, S.M. and K.C. Kapur (1973) 'An Algorithm for solving Multi-criteria Linear Programming Problems with Examples'. Operational Research Quarterly Vol. 24, 65-77.

Benayoun, R., J. Tergny and D. Keuneman (1970) 'Mathematical Programming with Multi-Objective Functions: A Solution by P.O.P.' Metra Vol. 9, 279-299.

Benayoun, R., J. de Montgolfier, J. Tergny and O. Larichev (1971) 'Linear Programming with Multiple Objective Functions: Step Method (STEM).' Mathematical Programming Vol. 1, 366-375.

Bergsman, J. and A.S. Manne (1966), 'An Almost Consistent Intertemporal Model for India's Fourth and Fifth Plans' in I. Adelman and E. Thorbecke (eds.) The Theory and Design of Economic Development John Hopkins University Press, Baltimore.

Bhagwati, J.N. and S. Chakravarty (1969) 'Contributions to Indian Economic Analysis: A Survey' American Economic Review Vol. 59, Supplement to No.4.

Bruno, M. (1966) 'A Programming Model for Israel' in I. Adelman and E. Thorbecke (ed.) The Theory and Design of Economic Development. John Hopkins University Press, Baltimore.

Burroughs Corporation (1975) B7700/B6700 Systems TEMPO Mathematical Programming System. User's Manual. Detroit, Michigan 48232.

Central Bank of Ceylon (1964) Survey of Ceylon's Consumer Finance 1963, Columbo.

Central Bank of Ceylon (1974) Survey of Ceylon's Consumer Finance 1973, Colombo.

Central Bank of Ceylon (1978) Review of the Economy 1978. Colombo.

Central Bank of Ceylon (1979a) Annual Report of the Monetary Board to the Hon. Minister of Finance and Planning for the year 1979, Colombo.

Central Bank of Ceylon (1979b) Review of the Economy 1979. Colombo.

Central Bank of Ceylon (1980) Review of the Economy 1980. Colombo.

Central Bank of Ceylon (1981) Economic and Social Statistics of Sri Lanka Vol. IV No.1

Chakravarty, S. (1969) Capital and Development Planning M.I.T. Press, Cambridge, Mass.

Chakravarty, S. and R.S. Eckaus (1964) 'An Approach to a Multisectoral Intertemporal Planning Model' in P.N. Rosenstein-Rodan (ed.) Capital Formation and Economic Development, M.I.T. Press, Cambridge, Mass.

Charnes, A. and W.W. Cooper (1961) Management Models and Industrial Applications of Linear Programming Vol. 1, Wiley, New York.

Chenery, H.B. (1979) Structural Change and Development Policy. Oxford University Press, New York.

Chenery, H.B., M.S. Ahluwalia, C.L.G. Bell, J.H. Duloy and R. Jolly (1974) Redistribution with Growth Oxford University Press, New York.

Chenery, H.B. and M. Bruno (1962) 'Development Alternatives in an Open Economy' Economic Journal Vol. 72, 79-103.

Chenery, H.B. and K. Kretschmer (1956) 'Resource Allocation for Economic Development'. Econometrica Vol. 24, 365-399.

Chenery, H.B. and A.M. Strout (1966) 'Foreign Assistance and Economic Development' American Economic Review Vol. 56, 679-733.

Chenery, H.B. and H. Uzawa (1958) 'Non-Linear Programming and Economic Development' in K.J. Arrow, L. Hurwicz and H. Uzawa (eds.) Studies in Linear and Non-Linear Programming, Stanford University Press, Stanford.

Clark, P.B. (1975) 'Intersectoral Consistency and Macroeconomic Planning' in C.R. Blitzer, P.B. Clark and L. Taylor (eds.) Economy-Wide Models and Development Planning. Oxford University Press, Oxford.

Codippily, H.M.A. (1979) Inter-relationships between Income Redistribution and Economic Growth with special reference to Sri Lanka. Ph.D. Thesis, University of Warwick, Coventry.

Cohon, J.L. (1978) Multiobjective Programming and Planning Academic Press, New York.

Cohon, J.L. and D.H. Marks (1973) 'Multiobjective Screening Models and Water Resources Investment'. Water Resources Research Vol. 9, 826-836.

Cohon, J.L. and D.H. Marks (1975) 'A Review and Evaluation of Multi-objective Programming Techniques' Water Resources Research Vol. 11, 208-220.

Dahanayake, P.A.S. (1977) Economic Policies and their Implications for Foreign Exchange Availability in Sri Lanka. 1956-1972. Central Bank of Ceylon Research Series, Colombo.

Dahanayake, P.A.S. (1979) 'Growth and Welfare: Some Reflections in the Effects of Recent Development Policy Reforms in Sri Lanka' Central Bank of Ceylon Staff Studies Vol. 9, 33-45.

Dasgupta, P., A. Sen and S. Marglin (1972) 'Guidelines for Project Evaluation' United Nations, New York.

Deaton, A.S. and J. Muellbauer (1980) Economics and Consumer Behaviour. Cambridge University Press.

De Melo, M.H. (1978) A General Equilibrium Investigation of Agricultural Policies and Development Strategies: A case study of Sri Lanka. Ph.D. Thesis, University of Maryland.

Delft, A. Van and P. Nijkamp (1976) 'The use of Hierarchical Optimization Criteria in Regional Planning.' Research Memorandum No.41, Dept. of Economics, Free University, Amsterdam.

Delft, A. Van and P. Nijkamp (1977) Multi-criteria Analysis and Regional Decision Making, Martinus Nijhoff, Leiden.

Department of National Planning (1962) The Short-Term Implementation Programme, Colombo.

Dervis, H, J. de Melo and S. Robinson (1982) General Equilibrium Models for Development Policy. Cambridge University Press.

Domar, E.D. (1957) 'A Soviet Model of Growth' in Essays in the Theory of Growth' Oxford University Press, New York.

Eckaus, R.S. and K.S. Parikh (1968) Planning for Growth: Multi-sectoral Intertemporal Models Applied to India M.I.T. Press, Cambridge, Mass.

Ecker, J.G. and I.A. Kouada (1975) 'Finding Efficient Points for Linear Multiple Objective Programmes'. Mathematical Programming Vol. 8, 375-377.

Evans, J.P. and R.E. Steuer (1973) 'A Revised Simplex Method for Linear Multiple Objective Programmes' Mathematical Programming Vol. 5, 54-72.

Fichefet, J. (1976) 'GPSTEM, An Interactive Multi-Objective Optimization Method' in A. Prekopa (ed.) Progress in O.R. Vol. 1 North-Holland, Amsterdam, 317-332.

Frank, M. and P. Wolfe (1956) 'An algorithm for Quadratic Programming' Naval Research Logistics Quarterly Vol. 3, 95-110.

Gass, S. and T. Saaty. (1955) 'The Computational Algorithm for the Parametric Objective Function' Naval Research Logistics Quarterly Vol. 2.

Geary, R.C. (1980-81) 'A Note on A Constant Utility Index of the Cost of Living' Review of Economic Studies Vol. 18, 65-66.

Geoffrion, A.M. and J.S. Dyer and A. Feinberg (1972) 'An Interactive Approach for Multi-Criterion Optimization' Management Sciences Vol. 19, 357-68.

Griffin, K. and J. Enos (1970) 'Foreign Assistance: Objectives and Consequences' Economic Development and Cultural Changes Vol. 18, 313-27.

Haimes, Y.Y. (1973) 'Integrated System Identification and Optimization' in Leondes (ed.) Control and Dynamic Systems. Advances in Theory and Applications. Academic Press, New York, 435-518.

Haimes, Y.Y. and W.A. Hall (1974) 'Multiobjectives in Water Resources Systems Analysis: The Surrogate Worth Trade-off Method' Water Resources Research Vol. 10, 615-624.

Haimes, Y.Y., W.A. Hall and H.T. Freedman (1975) Multiobjective Optimization in Water Resources Systems: The Surrogate Worth Trade-off Method. Elsivier Scientific, New York.

Hallett, A.J.H. (1981) 'Domestic Production Forecasts for Sri Lanka, 1980-84' Progress Vol. 1, Ministry of Plan Implementation, Colombo.

Holl, S. (1973) <u>Efficient Solution to a Multicriteria Linear Programme with Applied to an Institution of Higher Education</u>. Ph.D. Thesis, Dept. of Mathematical Sciences, John Hopkins University, Baltimore, Maryland.

Howe, H.J. (1975) 'Development of the Extended Linear Expenditure System from Simple Saving Assumption' <u>European Economic Review</u> Vol. 6, 305-10.

Hwang, C.L. and A.S.M. Masud (1979) <u>Multiple Objective Decision Making - Methods and Applications</u> Springer, Berlin.

Ignizio, J.P. (1976) <u>Goal Programming and Extensions</u>. Lexington Books, Massachusetts.

Ijiri, Y. (1965) <u>Management Goals and Accounting for Control</u>. North-Holland, Amsterdam.

International Labour Office (1971) <u>Matching Employment Opportunities and Expectations: A Programme of Action for Ceylon</u>, <u>Technical papers</u>, Geneva.

Isenman, P. (1980) 'Basic Needs: The Case of Sri Lanka' <u>World Development</u> Vol. 8, 237-58.

Jayawardena, L. (1970) 'Recent Approaches to Planning in Ceylon' in E.A.G. Robinson and M. Kindron (eds.) <u>Economic Development in South Asia</u>, Macmillan.

Jayawardena, L. (1974) 'Sri Lanka' in H.B. Chenery, M.S. Ahluwalia, C.L.G. Bell, J.H. Duloy and R. Jolly <u>Redistribution with Growth</u>. Oxford Univeristy Press.

Johanson, L. (1960) A Multisectoral Study of Economic Growth. North-Holland, Amsterdam.

Jones, G.W. and S. Selvaratnam (1972) Population Growth and Economic Development in Ceylon Marga, Colombo.

Jorgenson, D.W. (1961) 'The Structure of Multisector Dynamic Models' International Economic Review Vol. 2, 276-93.

Karlin, S. (1959) Mathematical Methods and Theory in Games, Programming and Economics. Addison Wesley, Reading.

Karunaratne, N.D. (1973) Techno-Economic Survey of Industrial Potential in Sri Lanka. Industrial Development Board, Sri Lanka.

Karunatilake, H.N.S. (1971) Economic Development in Ceylon, Praeger, New York.

Karunatilake, H.N.S. (1975) 'The Impact of Welfare Services in Sri Lanka on the Economy' Central Bank of Ceylon Staff Studies Vol. 6 (1), 175-202.

Karunatilake, H.N.S. (1978) 'Mr. E.L.H. Lee's Interpretation of Rural Poverty in Sri Lanka' Central Bank of Ceylon Staff Studies Vol. 8 (1), 79-92.

Keen, P.G.W. (1977) 'The Evolving Concept of Optimality' in M.K. Starr and M. Zeleny (eds.) Multiple Criteria Decision Making. North-Holland, Amsterdam.

Klein, L.R. and H. Rubin (1947-48) 'A Constant-Utility Index of the Cost of Living' Review of Economic Studies Vol. 15, 84-87.

Komiya, R. (1959) 'A Note on Prof. Mahalanobis Model of Indian Economic Planning' Review of Economics and Statistics. Vol. 41, 29-35.

Kuhn, H.W. and A.W. Tucker (1951) 'Non-linear Programming' in J. Neyman (ed.) Proceedings of the Second Berkeley Symposium on Mathematical Studies and Probability University of California Press, Berkeley, 481-93.

Kuznets, S. (1955) 'Economic Growth and Income Inequality' American Economic Review Vol. 45, 1-28.

Lakshman, W.D. (1976) 'Consumer Finance Survey Data on Income Distribution in Sri Lanka, 1963 and 1973: Some Mis-Interpretaions' Modern Ceylon Studies Vol. 7 (1&2), 162-175.

Lee, E.L.H. (1977a) 'Rural Poverty in Sri Lanka, 1963-73' in K. Griffin and A.R. Khan (ed.) Poverty and Landlessness in Rural Asia, I.L.O., Geneva.

Lee, E.L.H. (1977b) 'Development and Income Distribution: A Case Study of Sri Lanka and Malaysia' World Development Vol. 5 (1) 278-89.

Lee, S.M. (1972) Goal Programming for Decision Analysis Auerbach Publishers, Philadelphia, Pennsylvania.

Little, I.M.D. and J.A. Mirrless (1969) Manual of Industrial Project Analysis in Developing Countries. Volume 11: Social Cost Benefit Analysis, OECD.

Little, I.M.D. and J.A. Mirrless (1974) Project Appraisal and Planning for Developing Countries. Heinemann Educational Books. London.

Loucks, D.P. (1975) 'Planning for Multiple Goals' in C.R. Bilitzer, P.B. Clark and L. Taylor (eds.) Economy-Wide Models and Development Planning Oxford University Press, Oxford. 213-233.

Lluch, C. (1973) 'The Extended Linear Expenditure System' European Economic Review Vol. 4, 21-32.

Lluch, C., A.A. Powell and R.A. Williams (1977) Patterns in Household Demand and Savings Oxford University Press.

Maass, A., M. Hufschmidt, R. Dorfman, H. Thomas, S. Marglin and G. Fair (eds.) (1962) 'Design of Water Resources Systems' Harvard University Press, Cambridge, Massachusetts.

Major, D. (1969) 'Benefit-Cost Ratios for Projects in Multiple Objective Investment Programmes' Water Resources Research Vol. 5.

Mahalanobis, P.C. (1953) 'Some Observations on the Process of Growth of National Income' Sankhya, September Vol. 12.

Mahalanobis, P.C. (1955) 'The Approach of Operational Research to Planning in India' Sankhya, December Vol. 16.

Manne, A.S. (1974) 'Multisectoral Models for Development Planning: A Survey' Journal of Development Economics Vol. 1, 43-69.

Manne, A.S. and A. Rudra (1965) 'A Consistency Model of India's Fourth Plan' Sankhya Series B Vol. 27.

Marglin, S. (1967) Public Investment Criteria George Allen & Unwin Ltd., London.

McKinnon, R.I. (1964) 'Foreign Exchange Constraints in Economic Development and Efficient Aid Allocation' Economic Journal Vol. 74, 388-409.

Miller, D.L. and D.M. Byers 'Development and Display of Multiple Objective Project Impacts' Water Resources Research, Vol. 9, 11-20.

Ministry of Planning and Employment (1971) The Five Year Plan, 1972-76. Colombo.

Ministry of Finance and Planning (1980) Public Investment, 1980-1984. Colombo.

Ministry of Finance and Planning (1981) Public Investment, 1981-1985. Colombo.

Morawetz, D. (1980) 'Economic Lessons from Some Small Socialist Developing Countries' World Development Vol. 18, 337-69.

National Planning Council (1959) The Ten Year Plan. Colombo.

Nelson, R. (1970) 'The Effective Exchange Rate: Employment and Growth in a Foreign Exchange Constrained Economy' Journal of Political Economy Vol. 78, 546-64.

Newbery, D. (1972) 'Public Policy in the Dual Economy' Economic Journal Vol. 82, 567-90.

Nijkamp, P. and P. Rietveld (1976a) 'Multi-Objective Programming Models: New Ways in Regional Decision Making' Regional Sciences and Urban Economics Vol. 6, 253-274.

Nijkamp, P. and P. Rietveld (1976b), 'Properties of Multi-Objective Optimization Models' Research Memorandum 57, Dept. of Economics, Free University, Amsterdam.

Nijkamp, P. (1977) Theory and Applications of Environmental Economics. North-Holland, Amsterdam.

Paukert, F. (1973) 'Income Distribution at Different Levels of Development: A Survey of Evidence' International Labour Review Vol. CVIII (2-3), 97-125.

Philip, J. (1972) 'Algorithms for the Vector Maximization Problem' Mathematical Programming Vol. 8, 375-377.

Pyatt, G., A.R. Roe and Associates (1978) Social Accounting for Development Planning with special reference to Sri Lanka. Cambridge University Press, Cambridge.

Pyatt, G. and J.I. Round (1979) 'Accounting and Fixed Price Multipliers in a Social Accounting Matrix Framework' Economic Journal Vol. 89, 850-73.

Rietveld, P. (1980) Multiple Objective Decision Methods and Regional Planning North-Holland, Amsterdam.

Rudra, A. (1975) Indian Plan Models Allied Publishers, India.

Samuelson, P.A. (1947-48) 'Some Implications of Linearity' Review of Economic Studies Vol. 15, 88-90.

Sirisena, N.L. (1976) A Multisectoral Model of Production for Sri Lanka. Central Bank of Ceylon Research Series, Colombo.

Spronk, J. (1980) Interactive Multiple Goal Programming for Capital Budgeting and Financial Planning. Ph.D. Thesis, Erasmus University, Rotterdam.

Starr, M.K. and M. Zeleny (1977) 'MCDM - State and Future of Arts' in M.K. Starr and M. Zeleny (eds.) Multiple Criteria Decision Making, North-Holland, Amsterdam, 5-29.

Stern, N.H. (1972) 'Optimum Development in a Dual Economy' Review of Economic Studies Vol. 39, 171-184.

Steuer, R.E. (1977) 'An Interactive Multiple Objective Linear Programming Procedure' in M.K. Starr and M. Zeleny (eds.) Multiple Criteria Decision Making North-Holland, Amsterdam.

Steuer, R.E. and A.T. Schuler (1978) 'An Interactive Multiple Objective Linear Programming Approach to a Problem in Forest Management' Operations Research Vol. 26, 254-269.

Stone, R. (1954) 'Linear Expenditure System and Demand Analysis: An Application to the Pattern of British Demand' Economic Journal Vol. 64, 511-27.

Tantasuth, V. (1975) Goal Programming and Long Range Planning in Underdeveloped Countries Ph.D. Thesis, Texas Tech. University.

Taylor, L. (1975) 'Theoretical Foundations and Technical Implications' in C.R. Blitzer, P.B. Clark and L. Taylor (eds.) Economy-Wide Models and Development Planning, Oxford University Press, Oxford.

Tendulkar, S.D. (1971) 'Interaction between Domestic and Foreign Resources in Economic Growth: Some Experiments for India' in H.B. Chenery (ed.) Studies in Development Planning. Harvard University Press, Cambridge.

Tyler, G. and A.R. Roe (1977) 'An Approach to Social Accounting for Welfare Planning' Warwick Economic Research Papers. No. 108. Department of Economics, University of Warwick.

Tyler, G. and A.R. Roe (1977a) 'Key Sector Identification with Multiple Objectives: Some Further Results' Warwick Economic Research Papers. No. 118, Department of Economics, University of Warwick.

von Neumann, J. (1945) 'A Model of General Economic Equilibrium' Review of Economic Studies Vol. 13, 1-9.

Waltz, P.M. (1967) 'An Engineering Approach to Hierarchical Optimization Criteria' IEEE Transaction Automatic Control Vol. AC-12 No. 2 179-180.

Weisskopf, T.E. (1971) 'Alternative Patterns of Import Substitution in India' in H.B. Chenery (ed.) Studies in Development Planning, Harvard University Press, Cambridge.

Yu, P. (1973) 'A Class of Decision for Group Decision Problems' Management Sciences Vol. 19.

Zadeh, L.A. (1963) 'Optimality and Nonscalar-Valued Performance Criteria' IEEE Trans. on Automatic Control Vol. AC-8 No. 1, 59-60.

Zeleny, M. (1974) Linear Multiobjective Programming Springer-Verlag, New York.

Zionts, S. and J. Wallenius (1976) 'An Interactive Programming Method for Solving the Multiple Criteria Problem' Management Science Vol. 22, 652-663.

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