

A COMPREHENSIVE THREE-LEVEL DEVELOPMENT PLANNING MODEL*

A Practical Decentralization Planning Approach For the Underdeveloped Countries

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ABSTRACT :

The need for well-defined approaches to the problems is as acute as the problems confronting the underdeveloped countries. The various actors in the state of the underdeveloped countries; the politicians, the economics, the administrators, and the sociologists have attempted to see the problems concerned in their own way. It is the aim of this paper to elaborate a decentralization practical approach to national economic planning in underdeveloped countries. An attempt is made here to establish a self-consistent formal planning model by utilizing mathematical programming, input-output, and cost-benefit analysis. Corresponding to the national, sectorial, and project level the model

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proposes and integrated system consisting of a multisectorial model, sectorial models, and a suitable criterion for project evaluation. The interrelationships among the sectors and the feedback between the variables of the whole system are being considered as well. In one version of the model the functional equations consist of variables relating to different points of time, and in this sense the model may be used to formulate a multi-period plan.

The model does not approach the problem of optimal planning from the private point of view, but instead it tackles the problem from the national point of view by ascertaining the role of state in national economic planning. The state intervention is created by the existence of economic, social, and political conditions of the underdeveloped countries. The activities of the private entrepreneur, however, may be affected to follow the policy of the state by a system of incentives and disincentives.

It is not the aim of this paper to claim that the proposed planning approach is applicable in all underdeveloped countries. This is due to the fact that there exists no universally accepted concept of the "underdeveloped countries." However, the model in its general form is flexible enough to be modified for particular application if necessary.

I. INTRODUCTION :

Very broadly, to accelerate economic growth in the underdeveloped countries⁽¹⁾ two ways are possible; Firstly, to increase the productivity of the resources in use by reallocating them in a more efficient manner; i.e. to minimize the waste of the available resources. Secondly, to create new productive capacity by utilizing the idle as well as new productive resources. The first is a reform of the economic structure whereas the second is a capital accumulation process. And while the former does

(1) "An underdeveloped country may be generally defined as a country which due to lack of capital goods and to the low level of knowledge and technical ability of the bulk of its population is unable to provide productive employment for all those who are otherwise able and willing to work. Except when such a country is endowed with exceptionally valuable natural resources, such a state will also result in a low standard of living." Al-Saadi, S.Z. [1], pp. 5-6.

not necessarily require new capital, the latter needs additional capital. It is to be emphasized that the efficient allocation of resources is necessary but not sufficient to achieve the targets of economic development, since this process would stabilize at a certain level of economic activities whereas economic development implies a continuous process of growth over time. However, both processes i.e. the creation of new productive capacity and the efficient allocation of resources are essential in the process of economic development.

Economic development springs from demand for necessities and ever-increasing human wants in relation to the scarcity of the economic resources. Hence the efficient utilization of these scarce resources is the essence of any social and economic development policy. And thus the only rational investment decisions would sustain the pace of development. In practice this fact creates the need to establish certain criteria for investment decisions at different levels of the economy and are to be applied for both private and public enterprises within a consistent framework of a comprehensive national plan.

In underdeveloped countries it is generally accepted that structural economic and social changes are required as preconditions for development. Such changes, however, cannot be carried out by the "weak" private entrepreneurs through the "imperfect" market system. Hence the state has to play a leading role in the course of economic development. It is of course acceptable too that the public and private activities have to be regarded as complementary and interrelated rather than mutually exclusive. But it is the state and not the private entrepreneur who should take the necessary measures and actions (in terms of providing the required level of investment, controlling the process of capital formation, influencing the level of private consumption) against the existing low level of per capita income, per capita saving (investment level), market imperfections, and, in general, the unbalanced structure of the economy. State intervention and actions should not be limited only to forecast the pattern of future development and its prospects but also to promote the economy and stimulating all economic activities in such a way as to increase the national and individual benefits and to reduce the economic and social costs of development.

II. DIFFERENT APPROACHES TO NATIONAL ECONOMIC PLANNING :

To clarify the theoretical basis of the proposed model presented in this paper, it may be useful to recall the economic reasoning, social and political conditions of different approaches to national economic planning. This would implicitly give the necessary justification of our model.

Theoretically, two main approaches for economic planning can be distinguished. Each approach reflects a different point of view; i.e. that of the individual consumers, the government as a consumer or as an investor, and of the businessmen. From the private entrepreneur's point of view, economic efficiency and in turn economic planning⁽²⁾ is to be considered within the framework of the ideal perfect competition of the market system where the private entrepreneur plays his role freely in response to the consumer's behaviour. In such a system prices reflect not only the importance of the products (goods & services) to the consumers and to the producers, but also when in free-market equilibrium they would maximize both the consumer's utility as well as the producer's profit and as a result a certain pattern of efficient allocation of resource as well as income distribution is settled. Prices would be equal to the marginal utility of the consumer as well as the marginal productivity (cost) of the corresponding factors of production. The growth of the economy will continue as long as the trend of investment always goes up because more profit lead to a higher level of investment, which will channel the available economic resources into the

(2) In this context the concept of "economic efficiency" is defined as to deal with the following problems :

- i) The problems of the efficient allocation of resources; this implies the problems of establishing criteria for investment.
- ii) The problem of economic growth; this introduced a time dimension into the problem of resources allocation.
- iii) Problems associated with the distribution of national output; this means the alleviation of income distribution problem.

Economic planning means a performance of mutually consistent actions aimed at achieving efficient solutions to the problems of growth, allocation of resources, and the distribution of output (income) under the prevailing state of technology and all other economic, social, and political conditions.

production of new capital goods, thus, acting as a motivator for growth.

In contrast to the laissez-faire mechanism, the command "socialist" economy tackles the problem of optimal planning from the extreme opposite direction; i.e. from the national point of view. The justification of this approach is that the concept of economic efficiency has its social, political as well as economic dimensions, and it is not conceivable unless the prevailing non-economic factors are to be taken into account. In practice, this takes the form of abolition of the private ownership of the means of production and the freedom of consumer choice. Economic planning by this approach could be carried out by the state — which is supposed to reflect the national point of view — to draw up a uniform national plan by which certain economic, social and political targets (state preference) are to be achieved. The economic reasoning given to support this approach may be stated as follows: Although there is no freedom of choice in consumption and labour occupation, the efficient allocation of resources — for given growth targets — can be directed by the state instead of the consumers preferences through a method of "trial and error." The prices calculated by the Central Planning Organization (CPO) will perform the task of the prices in the market system⁽³⁾.

In underdeveloped countries, the price mechanism of the market economy is not efficient to lead the economy towards the frontier of economic efficiency. This is due to many reasons associated with the existence of certain economic, social and political conditions. Nor is it practically possible to suggest that the mechanism of the "calculated" prices of the command socialist economic systems is suitable for the underdeveloped countries, since the positive way of judgment is to consider the facts (conditions) of the underdeveloped countries as they are and not as they should be.

III. Centralization and Decentralization Planning Procedures :

The proposed model owes its origin to Tinbergen's approach of planning by stages, but it cannot be directly related to the

(3) Lange, O. [13].

widely known planning procedures. It has some features which can be explained in view of the practical difficulties rather than good economic reasoning. The shortcoming of the proposed procedure, however, can not be assessed only in comparison with other decentralization planning procedures, but it should also be considered within the prevailing economic, social, and political conditions of the underdeveloped countries.

A multitude of planning procedures have been recently developed to deal with both the market and the socialist economies. For the market economies two main decentralization approaches have been suggested. The first follows the classical Schumpeter's growth model⁽⁴⁾ where profit-maximization is assumed to induce the private entrepreneur to play his "decisive" role in the process of development. A mathematically developed version of the model⁽⁵⁾ suggests that an optimization programming model is to be applied by the private entrepreneur who is assumed to have a complete knowledge about the changes in market prices, shadow prices, the state of technology, consumer's preferences, and the required supply of factors of production. By this model the leading private firms in the industry would maximize their profit and at the same time allocate their resources efficiently among their activities. This would force the inefficient firms — those with low levels of profit — either to modify their production plans or to get out of business. The micro (firm) model is then developed, at industry and macro level, to an aggregate dynamic programming model by which the growth of the economy and the optimal allocation of the national resources can be achieved. On the national level, the aggregated (macro) model can be used to forecast the effects of alternative fiscal policies implemented by the government⁽⁶⁾.

The second approach assumes that the decentralized planning procedure is to start from the national (macro) level down to the entrepreneur (micro) level. Economists have theoretically suggested that rational investment decisions on the micro-level are those satisfying the zero-profit optimality condition⁽⁷⁾. It is

(4) Schumpeter, J.A. [14].

(5) Cigno, A. [5].

(6) Cigno, A. [5].

(7) Dorfman, R. Samuelson, P.A., and Solow, R.M. [7].

implicitly assumed that set(s) of shadow prices are to be derived from a national planning model in order to be used afterwards by the private entrepreneur for project evaluation and investment decisions. The national planning model may be formulated as a mathematical programming problem describing the interrelationships of the planned economy so as to maximize (or minimize) a social welfare function subject to a number of economic, political, and technical constraints. The values of the dual variables are, therefore, to be used as efficiency prices for taking investment decisions on the micro level. This notion is being elaborated by A.R.G. Heesterman⁽⁸⁾ to deal with the problem of optimal allocation of the national resources in such a way as to reflect both the central (national) point of view as well as the role of prices and cost in a free exchange economy. By using the efficiency (shadow) prices derived from the (national) model, a policy of channelling investment in certain directions leading to the state of economic efficiency may be drawn up.

In the socialist economies, two conventional approaches to the decentralized planning procedures have been established. The first assumes that the CPO is to prepare set(s) of prices and objectives that are to be sent to the responsible bodies at the lower levels of the economic hierarchy in the form of parameters to guide them in constructing their production plans and evaluating their costs. These bodies responsible for the sectorial programmes and enterprise plans have to report back to the CPO stating their optimal production (target) plans and their requirements of resources on the basis of the CPO prices. According to the new information the CPO may introduce new sets of prices and objectives which are to be sent to the responsible economic organizations in order to modify their targets and requirements if necessary. This iterative procedure is to be continued until a satisfactory solution is reached⁽⁹⁾.

The second decentralization approach may be outlined as follows : The CPO chooses an initial allocation of the disposable resources — possible from traditional solutions — and sends it to the sectorial and enterprise levels. The CPO's proposals are

(8) Heesterman, A.R.G. [9].

(9) Technically the decomposition methods of a mathematical programming problem fit this procedure. See Dantzig, G. & Wolf, P. [6] and Kronsjo, T.O.M. [12].

to be considered by these bodies in order to draw up their optimal production (targets) plans and, at the same time, they have to estimate the shadow prices of their resources (may be the dual values of their optimization models) and send them to the CPO. On the basis of these shadow prices, the CPO will improve its initial solution, and new allocation of resources and targets may be arrived at. The new solution is to be sent again to the departments concerned and accordingly they have to change their plans and new sets of shadow prices may be derived. This procedure is to continue until a satisfactory solution for both the CPO and all enterprises is reached⁽¹⁰⁾.

IV. A Comprehensive Three-Level Development Planning Model :

Corresponding to the national, sectorial and micro level the proposed planning model consists of a multisectorial optimization model, sectorial 0-1 integer programming model, and an investment criterion for project evaluation. On the national level the model aims to maximize the growth of the economy; to reallocate the available scarce resources — capital and foreign exchange; to determine the production and consumption levels, and to ensure a minimum level of employment. It also permits the possible substitution of competitive imports by domestic output. The multi-sectorial model is assumed to be constructed by the Central Planning Organization to reflect the aims and the economic, social and political constraints restricting the economic development of the country concerned. The structural constraints cover the main macro-relations; i.e. the balanced relations of supply and demand, foreign trade activities, production functions, and resource utilization. At the sectorial level a 0-1 integer programming model is designed to select the projects of the national plan. Different Economic Departments (ED) are assumed to be responsible for constructing and solving the sectorial models. However, these decisions are not separated from the allocation pattern of resources and activities on the sectorial level although project's evaluation is to be carried out outside the sectorial model according to a certain investment criterion.

(10) Kornla, J. & Liptak, T.G. [11].

The planning process of the underdeveloped economy takes a form of iterative procedure. In the first stage the values of the endogenous economic variables on the macro and sectorial level are to be derived by solving the multi-sectorial model and accordingly the projects of the plan (to be evaluated separately) are to be chosen on the sectorial level by implementing the sectorial integer programming model. In the second stage, the effects of the first selection of the plan's projects should be assessed on the macro as well as the sectorial level. The multi-sectorial model should be solved again and new "sectorial" values of the variables may be obtained. Accordingly, the sectorial model is to be modified and solved again, and if a new solution is derived then the multi-sectorial model has to be modified again. The process has to be repeated until no new solution from the sectorial model is obtained. The convergency of iterations has not been mathematically proven. Such a proof remains open; however, from a practical point of view this proof is not necessary since the number of the proposed projects of the plan is finite. Thus one may consider the convergence state of iterations as the state where no new solution is derived by the sectorial integer programming model.

V. 1. General Economic and Technical Assumptions :

The model is based on a number of economic and technical assumptions. The economic assumptions are made in accordance with the general economic structure of the underdeveloped countries. The technical assumptions are related to the input-output analysis and linear programming technique. To make the model as practical as possible rather than purely theoretical, the limitation of the available data would also be considered. Some of these basic assumptions are as follows :

Firstly, capital (investment) is a capacity creating as well as income generating factor and it is the most scarce resource in underdeveloped countries. Likewise, foreign exchange is a scarce factor as well as being a growth limiting factor. Therefore, one of the main aims of the model is to allocate, efficiently, the available capital and foreign exchange among different sectors and projects.

Secondly, the rate of growth of the labour force is assumed sufficient to maintain the rate of growth of output, and as long as there exists widespread unemployment of different types, i.e. labour supply in excess of what can be employed by the available stock of capital, labour should not be considered as a limiting constraint on development. It is also assumed that a certain level of employment is necessary to be secured despite the labour cost. This assumption would serve both in :

- (a) Avoiding the most likely social and political disturbances during the plan period.
- (b) Increasing demand which has a positive effect on the expansion of the economy, provided that consumption should be within certain limits determined by the plan.

Thirdly, the model maintains general equilibrium between supply and demand through the balance relations among different sectors of the economy, the policy and behaviour relations (i.e. balance of payments, consumption and investment levels). It is thus assumed that prices during the plan period remain unchanged and all goods are estimated at the prices of the base year.

Fourthly, a simple type of production function (capital-output ratios) is to be used⁽¹¹⁾, and a suitable treatment to improve its estimation is suggested. The production technology of the plan's projects and its effects on the inter-industry system are being considered, i.e. the new technology of the new projects which is supposed to be implemented during the plan's period is to be taken into account.

Fifthly, the model covers a period of about five years because in underdeveloped countries political considerations necessitate that the projects should bear fruit within a relatively short period of time⁽¹²⁾.

(11) In this respect, in fact, we do accept the stability of the capital-output ratios at least for the medium term.

(12) "This limitation is not serious in the typical underdeveloped economy, in which capital goods (except for construction) are normally imported, and hence the possibility of achieving given levels of production is practically independent of the sequence of investment". Chenery, H.B. & Kretschmer, K. [4] p. 368.

Sixthly, regarding the investment projects of the plan, it is assumed that they will add new capacity in the same period. However, in practice the gestation period of many investment projects may be longer than the plan's period. In this case the new capacity should be considered in the present period as well as the next period. But initially we might assume that the economy is working at full capacity — the main reason for this assumption is most likely to be the lack of data — but if there are enough data we can consider additional capacity due to the implementation of the projects in the previous period.

Seventhly, in introducing a distinction between competitive and complementary imports the model allows the possible substitution of competitive imports by domestic products.

Eighthly, the income distribution problem is to be dealt with through maintaining a certain level of employment and consumption limits.

V. 2. Definitions and Notations :

(4.2.1.) Endogenous Variables :

- C_i^p is a scalar, C^p is a vector of private consumption of each sector i at the target year;
- I_i is a scalar, I is a vector of investment (by destination) of each sector i at the target year;
- M_i is a scalar, M is a vector of competitive imports of each sector i at the target year;
- \bar{M}_i is a scalar, \bar{M} is a vector of complementary imports of sector i at the target year;
- X_i is a scalar, X is a vector of total output of each sector i at the target year;
- I_i^o is a scalar, I is a vector of investment (by origin) of each sector i at the target year;
- Pro_{ij} Project j in the i^{th} sector ;
- I_{ij} is the output of capital goods of i^{th} sector held by j^{th} sector ;
- Y is the national income.

(4.2.2.) Exogenous Variables :

- C_i^g is a scalar, C^g is a vector of government consumption of sector i at the target year;
- E_i is a scalar, E is a vector of exports level of each sector i at the target year;
- Px_j is a scalar, Px is a vector of output of each sector j at the base year of the plan;
- B is the desired level of net balance of payments ;
- L is the minimum level of employment required by all sectors at the target year;
- PCa is the existing production capacity (capital stock) at the initial year of the plan;
- fc total financial resources (private and government saving plus foreign loans and grants) available for investment (purchasing capital goods) during the plan's period;
- \bar{I}_i is a scalar, \bar{I} is a vector of the minimum level of investment of each sector i to be maintained during the plan's period;
- \bar{X}_i is a scalar, \bar{X} is a vector of the minimum level of output of each sector i to be maintained at the target year;
- FL total foreign loans.

(4.2.3.) Parameters and Technical Coefficients :

- a_{ij} technical coefficients express the amounts of output of the i th industry (sector) which are required as inputs for one unit of output of the j th industry (sector);
- C_i is a scalar, C is a vector of the incremental capital-output ratio of each sector i of the economy;
- f refers to the total plan's period, e.g. five years;

- δ_{ij} technical coefficients reflecting the proportionate distribution of the output of capital goods of i^{th} sector which is held by j^{th} sector ;
- H is a matrix of sector-wise incremental capital-output ratios;
- $am_{,i}$ is value (amount) of complementary imports currently used in producing one unit of output in sector i ;
- $am_{P,i}$ is value (amount of complementary imports currently used for private consumption of commodities produced in sector i ;
- $am_{G,i}$ is value (amount) of complementary imports currently used for government consumption of commodities produced in sector i ;
- s^P is the propensity to save of the private sector;
- s is the propensity to save of the government sector;
- β_i is the elasticity of demand for output of sector i at certain reference points (per capita consumption of the output of sector i and per capita aggregate consumption).

V. 3. The Formulation of the Multi-Sectorial Model
Quasi-Static Version)

The mathematical formulation of the proposed multi-sectorial model may be written as follows :

$$(1) \quad \sum_{i=1}^n C_i^P + \sum_{i=1}^n I - \sum_{i=1}^n M_i = \sum_{i=1}^n \bar{M}_i = \text{Max.}$$

$$(2) \quad X_{i,t} + M_{i,t} - \sum_j a_{ij} X_{j,t} - \frac{2}{f-1} \geq \sum_j h_{ij} x_{i,t} - C_{i,t}^P$$

$$C_{i,t}^S + E_{i,t} - \frac{2}{f-1} \sum_j h_{ij} P_X - \frac{f+1}{f-1} I^* \geq 0$$

(j, i = 1, 2 ... n)
(t = the target year)

$$(3) \quad \sum_{i=1}^n g_i M_i + \sum_{i=1}^n g_i \bar{M}_i - \sum_{i=1}^n e_i E_i \leq B$$

$$(4) \quad \sum_{i=1}^n \bar{M}_i - \sum_{i=1}^n am_{,i} X_i - \sum_{i=1}^n amp_{,i} C_i^P - \sum_{i=1}^n amg_{,i} C_i^P = 0$$

$$(5) \quad \sum_{i=1}^n W_i X_i \geq L$$

$$(6) \quad \sum_{i=1}^n C_i X_i \leq fc + Pca$$

$$(7) \quad \sum_{i=1}^n C_i X_i - \sum_{i=1}^n I_i = \sum_{i=1}^n C_i P x_i$$

$$(8) \quad C_i^P \geq 0.90 (\beta_i \sum_i C_i^P + a_i) \\ (i = 1, 2 \dots n)$$

$$(9) \quad C_i^P \leq 1.10 (\beta_i \sum_i C_i^P + a_i) \\ (i = 1, 2 \dots n)$$

$$(10) \quad I_i \geq \bar{I}_i \\ (i = 1, 2 \dots n) \\ (\text{not necessarily all } i\text{'s})$$

$$(11) \quad X_i \geq \bar{X}_i \\ (i = 1, 2 \dots n) \\ (\text{not necessarily all } i\text{'s})$$

Initially it is assumed that the objective function of the multi-sectorial model is to maximize national income at the target year of the plan as it is the ultimate aim of economic development, i.e. to maximize Y where,

$$Y = \sum_i C_i^P + \sum_i C_i^G + \sum_i I_i + \sum_i E_i - \sum_i M_i - \sum_i \bar{M}_i$$

($i = 1, 2, \dots, n$ = total number of the sectors of the economy) But C_i^G and E_i are assumed to be exogenously determined; therefore the objective function becomes as stated in relation (1). The coefficients of the variable of the objective function are assumed to reflect both the government qualitative policy regarding the desired distribution of the standard of living (per capita consumption) between different social classes, the production structure consequent upon a given allocation of gross capital formation, and imports policy. In practice, the coefficients of the preference function can be chosen so as to reflect the politician's point of view⁽¹³⁾. Initially, it is assumed that there is no particular qualitative policy regarding these variables. So all the coefficients are assumed to be one. Other economic targets like the necessity of maintaining certain levels of private consumption and investment are to be dealt with by formulating suitable set(s) of constraints.

System (2) reflects the balance relations of the economy. Here, input-output analysis is used to ensure that output is uniquely determined as a linear combination of multi-sectorial demands given certain technological coefficients and final demand. This implies that the output of the whole economy must, in equilibrium, be equal to the sum of inter-industry (intermediate) demand for inputs plus the sum of "final demands" for output. In contrast to the open "version" of Leontief model where all final demand categories are exogenously determined outside the model, the closed Leontief model — which we follow considers private consumption, investment, competitive imports as endogenous variables, whereas the other final demand categories, i.e. government consumption, exports and net increase

(13) Professor Ranger Frisch [8] believes that a compromise preference function (of different targets) as well as a compromise weight of the coefficients of this function is possible to achieve.

of inventory (if available)⁽¹⁴⁾ are exogenously estimated and hence the output required from domestic production sectors plus the level of competitive imports to meet those types of demands are determined endogenously by the model. Mathematically :

$$X_i + M_i - \sum_{j=1}^n a_{ij} X_j - C_i^P - I_i^* = C_i^P + E_i \dots\dots (2-a)$$

The transformation process of investment by destination I into investment by origin I* is conceivable by multiplying the sector-wise capital-output ratios by the corresponding level of output. Explicitly :

$$\text{where, } I_j = C_j X_j \dots\dots (2-b)$$

\bar{X}_j is a scalar, \bar{X} is a vector of net increase of output of jth sector. But I_j consists of various types of capital goods and if this structure is given then the proportionality of I_j among these capital goods can be assumed.

$$\text{i.e. } I_{ij} = \gamma_{ij} I \dots\dots (2-C)$$

$$\text{clearly } \sum_j \gamma_{ij} = 1$$

By (2-b) and (2-C) we get ;

$$I_{ij} = \gamma_{ij} C_j \bar{X}$$

or

$$I_{ij} = h_{ij} \bar{X}_j \dots\dots (2-e)$$

where,

$$h_{ij} = \gamma_{ij} C_j$$

In a matrix notation, relation (2-e) can be rewritten as

$$I^* = H \bar{X}$$

(14) Net change in stock during the plan's period may be assumed to be nil algebraically. At the same time inventory value is generally of no significance in the underdeveloped countries. Thus we omitted inventory from the final demand categories.

Relation (2-e) may, therefore, be rewritten as follows :

$$X_i + M_i - \sum_j a_{ij} X_j - \sum_j h_{ij} \bar{X}_j = C_i^P + C_i^S + E_i \quad (2-g)$$

(i, j = 1, = ... n)

For a certain period of time (say five years) relation (2-g) is of a static nature. It implies that investment has to be spent in the target year of the plan⁽¹⁵⁾. This is not a very realistic assumption. In this respect a "quasi-static" approach which is being suggested by A.R.G. Heesterman⁽¹⁶⁾ is more realistic. It considers the dynamic nature of investment over time by assuming a linear time path for investment over time. Mathematically:

$$\sum_{t=0}^{f-1} I_t^* = \frac{1}{2} (f+1) I_0^* + \frac{1}{2} (f-1) I_f^* \quad \dots \dots (2-h)$$

By (2-h), (2-e) and (2-a), we derive the "quasi-static" balance relation as stated in system (2).

System (3) reflects the foreign trade balance. In most underdeveloped countries, the balance of payments imposes a constraint on investment programmes for development. If the imports level decreases, the gross national product will accordingly decrease unless investment is directed to import substitutions and to increase exports level. In order to avoid bottlenecks in the economy during the period of the plan and to explore the scope of substituting competitive imports by domestic products, imports are assumed to be of two types; competitive and complementary imports. Competitive imports are assumed to be homogenous with products of the corresponding domestic sectors and thus they could conceivably be replaced by increasing the level of domestic output. Complementary imports are those required during the period of the plan, where it is not possible to produce them locally. Thus complementary imports used for government consumption are assumed to be exogenous.

(15) In relation (2-g) the capacity creating effect of investment is taken into account, and if we are interested only in the change of the variables over two points of time say $t, t + 1$ then this relation can be considered as a dynamic one.

(16) Heesterman, A.R.G. [9], pp. 91-92.

Exports are assumed to be determined exogenously on the basis of the following :

- (i) the trend of exports in previous years;
- (ii) the demands of the foreign markets and the possible change of prices at the foreign markets during the period of the plan;
- (iii) the official foreign trade agreements with other governments.

For the desired level of net balance of payments (B) three cases are possible :

- (i) If $B > 0$, then B is the maximum deficit allowed;
- (ii) If $B < 0$, then B is the minimum surplus which must be achieved;
- (iii) If $B = 0$, then we have an equilibrium state i.e. total exports plus net income from abroad and foreign loans are equal to total imports plus net income to abroad.

System (4) is the definition constraint of the non-competitive imports.

System (5) expresses the employment "social target" constraint. One of the main aims of the economic plans in underdeveloped countries is to ensure a certain level of employment. This constraint (objective) may be in some sectors a binding one because of the necessity of avoiding any social or political disturbances resulting from the existence of widespread unemployment (real or disguised). The formulation of this constraint does not mean that the model considers labour as having no social cost, which may be true in some cases, but the approach of the model to the employment problem is to appreciate the social and political conditions for the success of the plan's implementation rather than for a purely theoretical consideration.

Equation (6) deals with the capital requirements. Total capital available to finance investment projects of the plan should be exogenously estimated, and its allocation among different sectors is based on sectorial capital-output ratios in addition to the other constraints. Total financial resources (fc) are assumed

to be determined by the propensity to save and by the economic and political capacity of getting foreign loans.

Equation (7) is the definition constraint of investment. It is derived from its basic relation as follows :

$$I_i = C_i (X_i - PX_i)$$

and

$$\sum_{i=1}^n C_i X_i - \sum_{i=1}^n I_i = \sum_{i=1}^n C_i PX_i$$

where,

$$\sum_{i=1}^n C_i PX_i = PCa$$

Systems (8 to 11) are behaviouristic constraints related to the minimum level of private consumption, investment and output variables during the plan's period. The economic justification of these constraints is the fact that the present allocation of production and resources in the underdeveloped countries is far from being efficient. Thus it is necessary to avoid the possibility of having a situation where the level of these variables at the target year would be below their levels at the basic year. This situation would create many economic, social, and political problems⁽¹⁷⁾. From the technical point of view, these constraints should not be introduced in order to force the behaviour of the model in such a way that the level of certain variables would follow a certain path of growth. The whole system should not be overdetermined. In particular systems (8 & 9) are related to private consumption. It is originally based on the assumption that the level of private consumption from the output of sector *i* may be considered as a linear function of total private consumption via the elasticity of demand :

(17) This implies a certain qualitative policy where it is possible either to consume in the present and postpone investment later on, or to consume and invest simultaneously. The latter case is being followed and this entails a certain level of saving.

$$\text{i.e.} \quad C_i^P = \beta_i \sum_i C_i^P + a_i$$

where,

a_i is a constant at the same reference points corresponding to sector i .

But this treatment may make the model very rigid⁽¹⁸⁾. A more flexible assumption is to assume that the consumption pattern is able to vary within about 10% of the range of either side of the Engel curves as we have stated in (8 & 9)⁽¹⁹⁾.

System (10) is introduced in order to ensure a certain level of capital accumulation during the period of the plan, i.e. it is necessary to determine the lower bound of investment at the target year which should be at least equal to the level of the base year. This set of constraints is also required to tackle the situation where certain amounts (values) of investments are being already implemented as a part of the costs of projects during the previous period.

System (11) states that the production level of each sector of the economy should be at least the same level as that of the base year. The rate of output growth, however, is to be determined endogenously by the model.

(18) This relation is a linear approximation of the following non-linear function :

$$C_i^P = k \frac{(C_i)}{N} \alpha_i$$

at a reference (forecast) point $\left(\frac{\sum_i C_{i,0}^P}{N_0}, \frac{C_{0,i}^P}{N_0} \right)$

where,

N is population

α_i expenditure elasticity for sector i (commodity i) estimated for cross section and time series of consumer behaviour.

See Bruno, M. [2] and Simpson, D. [15].

(19) See Bruno, M. [2] and Simpson, D. [15].

V. 4. THE FORMULATION OF THE SECTORIAL MODEL :

For each sector of the economy (i.e. for i -where $i=1, 2, \dots, n$), the mathematical formulation of the 0-1 integer model may be written as follows :

$$(1) \quad \sum_{j=1}^r (SMP)_{ij} \text{ Pro}_{ij} = \text{Max.}$$

$$(2) \quad \sum_{j=1}^r d_{ij} \text{ Pro}_{ij} \leq X_i$$

$$(3) \quad \sum_{j=1}^r m_{ij} \text{ Pro}_{ij} \leq M_i + \bar{M}_i$$

$$(4) \quad \sum_{j=1}^r h_{ij} \text{ Pro}_{ij} \leq L$$

$$(5) \quad \sum_{j=1}^r q_{ij} \text{ Pro}_{ij} \leq E$$

$$(6) \quad \sum_{j=1}^r k_{ij} \text{ Pro}_{ij} \leq I_i$$

$$(7) \quad \text{Pro}_{ij} = 0 \text{ or } 1$$

(i = 1, 2 ... n)
(j = 1, 2 ... r)

The sectorial model is of 0-1 integer programming type and it is assumed to be used by different economic departments (ED) corresponding to different sectors of the economy in order to select the plan projects from a proposed list. Before applying the sectorial model, each department should evaluate all proposed projects according to a certain investment criterion. In this context social marginal productivity (SMP) is being suggested as a yardstick for evaluating each of the proposed projects in each

sector. SMP concept may be defined as the effect of increasing one unit of investment (capital) on several dimensions of the economy as the national balance of payments and total output⁽²⁰⁾. The values of SMP's are then to be used as the coefficients of the variables of the objective function of the sectorial model which is to be maximized. Each variable of the objective function represents a proposed project. (equation (1)).

Different types of constraints are being considered. These are related to the following economic relations :

- (i) Total output of the selected projects of each sector of the economy should not exceed total output of the corresponding sectors which is endogenously determined by the multi-sectorial model. Practically such a constraint is not necessary because of the existence of the capital constraints⁽²¹⁾. This relation is expressed by equation (2).
- (ii) Total imports of the selected projects in each sector of the economy should not exceed the permitted level of imports of the corresponding sector (equation (3)).
- (iii) Total exports of the selected projects in each sector of the economy should be at least equal to the total level of exports of the corresponding sector. (equation (5)).
- (iv) Equation (4) states that total employment of the selected projects in each sector of the economy should be at least equal to the corresponding level of employment which is endogenously determined by the multi-sectorial model.
- (v) Total investment (capital requirements) of all selected projects should not be more than total investment allocated to the corresponding sector by the multi-sectorial model.

(20) This definition coincides with Chenery's definition (Chenery, H.B. [3]) whereas in A.E. Kahn [10] the SMP is defined as the marginal unit of investment to national product only. Professor J. Tinbergen in his definition to the national welfare implies the same meaning of our definition. Tinbergen, J. [16].

(21) This point is to be clarified in section (V. 6. (ii)).

V. 5. PLANNING MECHANISM :

The planning process suggested here is of two stages. In the first stage the multi-sectorial model is to be constructed and solved by CPO; therefore, the values of output, private consumption, gross capital formation, the number of employees and a first approximation of the allocation of the available resources (capital and foreign exchange) among all sectors of the economy are determined. These values represent the desired changes in output, private consumption, investment, imports and employment level, which has to be achieved, during the period of the plan. Then after deriving these values the CPO will instruct the corresponding ED's to use these values as either upper or lower bounds of their corresponding constraints of the sectorial models. In this stage the planning process is carried out not only on the macro and sectorial levels, but also at the project level, at which the ED's should evaluate each proposed project according to the SMP criterion. Then the sectorial model can be applied for each sector in order to select a number of projects.

The implementation of each selected project — determined by the final solution of the sectorial model — will affect the path and the rate of growth of the economy. The net increase of output, investment, imports and employment will contribute to the expansion of the economy by affecting intermediate demand, imports, the level of employment and of course the level of investment and private consumption. So in the second stage the CPO will take all these effects into account and improve the first solution obtained from the multi-sectorial model at the first stage according to the changes brought about by the implementation of the selected projects during the plan's period. Thus the multi-sectorial model should allow :

- (i) Changes in coefficients of the technology matrix (input-output ratios) by taking into consideration the new technology of the selected projects. This means that the values of the intermediate demand would change as a result of, implementing the projects of the plan. Consequently the level of private consumption, total output and its allocation among the corresponding sectors would be changed. This modification makes it possible to take into account the effect of the new technology used by the selected projects.

- (ii) The increase of imports and exports obtained from the first stage will affect the values of the economic variables the second stage as follows :
- (a) In the case of a deficit, if the values of the exports level are greater than the level of imports, the deficit gap will be reduced and this of course would improve the balance of payments. But if the values of imports are greater than exports then the gap becomes wider and this would worsen the balance of payments.
- (b) In the case of a surplus, i.e. the values of exports are greater than imports, then the lower limit should be raised into a higher new level and this of course has a positive effect on the balance of payments, whereas if the values of imports are greater than exports, then the new lower limit will be less than the first stage.
- (iii) The first approximation of capital-output ratios will be adjusted according to actual figures of output and capital of the selected projects.

V. 6. ON THE MATHEMATICAL STRUCTURE OF THE MODEL :

- (i) **The multi-sectorial model :** The number of the endogenous variables of the model as it has been stated in section (V. 4) is greater than the number of total constraints. From a mathematical point of view this means that some of the activities (total number of the variables minus the number constraints) will have zero value. From the economic point of view this situation may be unrealistic because unless an economic justification is explicitly given, in terms of constraints, all economic activities should be always positive. This situation requires the following mathematical modification which will reduce the number of the variables without affecting the structure of the model.

Using the definition constraint of the non-competitive imports (system (4)) the objective function can be written as follows :

$$\text{Max } \sum_{i=1}^n C_i^P + \sum_{i=1}^n I_i - \sum_{i=1}^n M_i - \left(\sum_{i=1}^n a_{m,i} X_i + \sum_{i=1}^n a_{mp,i} C_i^P + \sum_{i=1}^n a_{mg,i} C_i^G \right)$$

In the second and the consequent iterations the incremental capital-output ratios, input-output coefficients of the interindustry system and input-output coefficients of the complementary imports are to be adjusted to \bar{C}_i , \bar{a}_{ij} , and \bar{a}_{mj} respectively.

- (ii) **The sectorial model :** In practice it is possible that we may face the situation where in order to satisfy the optimality conditions of the sectorial model it might be necessary not to choose a certain proposed project which is more or less near the efficiency frontier as determined by the model itself. Such a situation may arise due to two reasons :
- (a) the nature of the integer type problem where most likely some of the available resources would be wasted;
 - (b) the limited number of the proposed projects.

Both reasons are beyond the planner's control. With regard to the first one, since the variables take the integer values of either zero or one then from a mathematical point of view there is no alternative. Concerning the second reason, in reality the number of the proposed projects is really limited, in fact in some cases the number of the proposed projects is so small that there is no need even to compare between them looking for the most efficient one. However, to deal with such problems we may change the direction of the constraint related to the sectorial output level. Economically this is justified by the existence of the investment capacity constraint on the sectorial level as well as on the micro-level. Actually there is no harm in producing more output — provided no extra capital is required — or in other words by changing this constraint the model restricts the activities of the total number of projects of each sector to maintain a minimum level of output. This would be consistent with the behaviour output constraint of the multi-sectorial model. Therefore, the constraint of the sectorial model would be :

$$\sum_{j=1}^r d_{ij} \text{Pro}_{ij} \geq X_i$$

instead of

$$\sum_{i=1}^r d_{ij} \text{Pro}_{ij} \leq X_i \quad (\text{where } i = 1, 2, \dots, n)$$

In contrast to the multisectorial model, the exports and imports constraints of the sectorial model are dealt with separately. The economic reason for this treatment is the need to maintain a certain level of exports and not to exceed a required level of imports. But as an alternative, one may suggest that both constraints could be added such as the following :

$$\sum_{j=1}^r (m_{ij} - q_{ij}) \text{Pro}_{ij} \leq M_i + \bar{M}_i - E_i$$

Mathematically this may be useful because it reduces the number of the constraints and therefore it would increase the degree of freedom for each variable to take different values. But from the economic point of view the algebraic values of both exogenous constraints (imports and exports), and the coefficients of the variables $(m_{ij} - g_{ij})$ may not lead to satisfying our basic assumptions regarding the desirable levels of exports and imports.

V. 7. A MULTI-PERIOD VERSION OF THE MODEL :

The multi-sectorial model of one period could be converted to a multi-period model which would help in deriving the annual values of the endogenous variables involved, i.e. to formulate a detailed annual plan. The practical problems are the only restrictions which may prevent the application of the multi-period model instead of the multi-sectorial "quasi-static" model. These problems can be summarized as follows :

- (i) The number of the variables and the constraints will increase five times (in case of the five year's plan) and this may

make the task of solving the model rather difficult by the available "computer" capacity.

- (ii) The application of the multi-period model requires the annual values of the exogenous variables. This is not really a serious problem as long as the aggregate values of the exogenous variables are usually derived from the annual estimates.

The multi-period model can be constructed by adding only another set of constraints to link two successive periods by dynamic relations of investment and the existing capacity during the annual periods of the plan. This dynamic relation can be defined as follows. Total investment at the end of period (t) should be greater than or equal to the level of production capacity at the end of the same period minus production capacity at the end of the previous period, i.e. :

$$\sum_i I_i = \sum_i Ca_{i,t} - \sum_i Ca_{i,t-1} \quad \dots (a)$$

where,

Ca_i is a scalar, Ca is a vector of production capacity of the i^{th} sector.

but,

$$Ca_{i,t} = C_i X_i(t) \quad \dots (b)$$

where,

C_i is a scalar, C is a vector of capital-output ratio of the i^{th} sector.

$X_{i,t}$ is a scalar, X is a vector of output of i^{th} sector at period t .

similarly,

$$Ca_{i,t-1} = C_i X_i(t-1) \quad \dots (c)$$

by (b) and (c) we get

$$Ca_{i,t} - Ca_{i,t-1} = C_i (X_i(t) - X_i(t-1))$$

or,

$$I_{i,t} = C_i (X_{i,t} - X_{i,t-1})$$

and,

$$\sum_i I_{i,t} = \sum_i C_i (X_{i,t} - X_{i,t-1})$$

at time $t = 1$, we have

$$\sum_i X_{i,t-1} = PCa$$

where,

PCa is the production capacity of the economy at the initial year of the plan.

During the whole period (i.e. $t = 1, 2, 3, 4, 5$) we have,

$$\sum_i C_i X_{i,t} \leq PCa + \sum_i I_{i,t}$$

The objective function, balanced relation, and foreign trade constraints may be mathematically written as follows :

ii) The balanced constraints :

$$\begin{aligned} \text{to maximize} &= \sum_{i=1}^n C_{i,t}^P + \sum_{i=1}^n I_{i,t} - \sum_{i=1}^n M_{i,t} \\ &- \left(\sum_{i=1}^n a_{mi} X_{i,t} + \sum_{i=1}^n a_{mpi} C_i^P + \sum_{i=1}^n a_{mgi} C_i^P \right) \\ &(t = 1, 2, \dots, 5) \end{aligned}$$

ii) The balanced constraints :

$$\begin{aligned} M_{i,t} + X_{i,t} - \sum_{j=1}^n a_{ij} X_{j,t} - C_{i,t}^P - \sum_{j=1}^n h_{ij} X_{j,t} &\geq C_{i,t}^S + E_{i,t} \\ (i = 1, 2, \dots, n) \\ (t = 1, 2, \dots, 5) \end{aligned}$$

iii) Foreign trade constraint :

$$\sum_{i=1}^{n'} g_i M_{i,t} + \sum_{i=1}^n a_{mi} X_{i,t} \leq B + \sum_{i=1}^n a_i E_i + \sum_{i=1}^n a_{mpi} C_{i,t}^P + \sum_{i=1}^n a_{mgi} C_{i,t}^P$$

(t = 1,2 ... 5)

V. 8. Some General Remarks on the Model :

Firstly, the linearity assumption among the variables of both the objective function and the constraints may not in some cases reflect reality where relations are non-linear. The only justification of this assumption is the practical difficulty of both formulating and solving the model.

Secondly, with regard to the gestation period the model has a shortcoming and this is caused by practical difficulties arising especially when deriving the initial values of investment of the projects under construction. However, a suitable modification for the constant values of the sectorial model may be adequate to deal with this problem.

Thirdly, the sensitivity of the multi-sectorial model could be easily tested by changing the parameters (coefficients) of the investment constraints (i.e. incremental capital-output ratios), and by changing the value of the exogenous variables the impact of these variables on the pattern of growth can be shown.

Fourthly, the application of the sectorial model — for each sector of the economy — depends on the assumption that there exist many alternatives for proposed projects, and a complete list of them is to be ready. In practice in some sectors e.g. services, this may be difficult to achieve.

Fifthly, some practical problems; (i) in the case where it is proposed to expand an existing project rather than building a separate new one; this problem can be dealt with by revaluating the old project with its new expansion and can be considered as any other proposed project. In such a case the only measure

to be taken when applying the sectorial — model is the modification of the values of the exogenous variables which are to be used in the sectorial model, e.g. :

$$X_j \text{ is to be } X_j + P\bar{x}_j$$

where,

$P\bar{x}_j$ is total output of the old project to be yielded during the period of the plan.

- ii) Some of the projects have been under construction before the implementation of the plan. In this case there is no point in evaluating the project again, but it is necessary to subtract imports required by those projects from the imports values which are derived endogenously by the multi-sectorial model. Capital is also to be subtracted and labour and export values are to be considered at the stage during which we estimate them exogenously.
- iii) Some projects will be completed after the Plan's period. In this case we have to add to the endogenous values of total sectorial imports, total sectorial capital and to the exogenous values of labour and exports all the values of the corresponding variables of the proposed project.

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