Regional Specialisation in Metallurgical and Machine-Building Industries in India in the Framework of a Planning Model for Optimum use of National Resources*

I

If the supply functions for the various inputs at different sources and the demand functions for the outputs at different destinations were known, then given the transport costs and the production function the optimum location for an industry could be determined.[1] But for a growing economy, particularly, for a developing economy whose industrial base is rather small—these demand and supply conditions can never be assumed to be available as given data. This is particularly true for intermediate goods. The demand centres for intermediate goods depend on the locational decisions of the using industries ; the supply centres for some of its inputs would again, depend on the locational decisions of the industry itself. All this implies that for efficient resource-use, these interrelated planning problems should be solved simultaneously. But the state of arts in the computer technology today (or in near future) would not permit the numerical solution of any giant optimization planning model, which could give simultaneous answers to a planning authority's intertemporal, intersectoral and interregional allocation problems, even if such a model could be constructed realistically, and its mathematical solutions could be ensured.

This necessitates meaningful decomposition of the problem and search for useful results within partial frameworks. Such simplifications

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1. See for example A. Losch, *The Economics of Location*, Yale University Press, 1954 or L. Lefeber, *Allocation in Space*, North Holland Publishing Co. 1958.

are possible in a large number of alternative ways and should, obviously, depend on the nature of the answers one is interested in. One such model is attempted here for finding out the possible advantages in the regional specialisation in the development of the metallurgical and machine-building industries in India.

There are three forces that come into play in deciding locational pattern of industries : (*a*) absolute advantages of a region, *i.e.* the availability of natural resources, (*b*) cost of transportation and (*c*) the economies of scale. The first factor calls for the inclusion of mining activities—particularly coal and iron ore mining—within the framework of optimisation. For a meaningful formulation of the absolute advantages due to mining activities it is necessary to introduce constraints on the expansion of certain types of mining in certain regions. The resource costs due to transportation are difficult to estimate. That is why in this exercise, interregional transporation activity with appropriate production function is taken as an endogenous sector. An important input in these industries is electricity, whose production is heavily dependent on natural resources, and whose transmission over long distances is highly expensive. Therefore electricity generation is taken as another endogenous sector in this model.

Economies of scale in the production processes are ignored in this exercise. Every activity is assumed to have a fixed-coefficient Leontief technology with current and capital inputs. Economies of scale could meaningfully be introduced only at plant levels, and this would require a much finer regional disaggregation. This, along with high expenses of nonlinear programming, led to the exclusion of this factor. However, it should be noted that any economy of scale would call for a higher regional specialisation in production. Therefore, the specialisation (and consequent agglomeration of these industries) presented by this exercise is considerably understated compared to what efficiency in resource-use would demand in the presence of economies of scale.

In what follows a fifteen years planning model is constructed for India. In all, but the endogenous, sectors of the economy, growth paths are specified[2]. As for the endogenous sectors, each region (and also the whole economy) is given make-or-buy choices. Given arbitrary speci-

2. No serious attempt is made here to check the intersectoral and intertemporal consistency for the entire economy-wide planning model, although obviously lop-sided specifications are avoided.

fications of exports, exogenous imports, availability of foreign aid, and household and government consumptions, our planning problem is to reach the maximum level of domestic production in the endogenous sectors subject to an *a priori* specification regarding the sectoral composition.

It should be clearly noted that none of the solutions is meant to provide quantitatively correct investment allocations for India's planning problem. The object is to obtain certain qualitative results, namely make-or-buy decisions for each region, under variety of assumptions, and judged by the criterion of productive efficiency for the economy as a whole.

II

The planning period starts on April 1, 1960,[3] and ends on March 30, 1975. These fifteen years of planning period are divided into three equal time intervals of five years each. Only eight production sectors *plus* interregional transportation are taken as endogenous to the model ; these are :

(*i*) Coal
(*ii*) Iron Ore
(*iii*) Other Minerals
(*iv*) Iron and Steel
(*v*) Non-Ferrous Metals
(*vi*) Machinery and Equipment
(*vii*) Transport Equipment
(*viii*) Electricity
(*ix*) Inter-Regional Transportation

The other sectors of the economy are taken as exogenous in the planning model, *i.e.*, the time pattern of their productions during the planning period are fixed from outside. The level of aggregation at which these exogenous sectors are treated for the purposes of determining the demands for the products of the endogenous sectors is given in Table 2.

Geographically, India has been, in this study, divided into four regions ; their compositions are as follows :

Region I : Assam, West Bengal, Bihar, Orissa, NEFA, Tripura, Andaman, and Nicobar Islands.

3. Indian Fiscal Year is April-March. Most statistics refer to that period.

Region II : Uttar Pradesh, Madhya Pradesh, Rajasthan, Punjab, Jammu and Kashmir, Delhi, Himachal Pradesh.
Region III : Maharastra, Gujrat.
Region IV : Andhra Pradesh, Madras, Mysore, Kerala.

Initial conditions

The intial conditions for the model are given in terms of the productive capacities of the various industries in each region, (plus interregional transportation). Algebraically, they are

$$X_i^\delta(0) \leqslant \overline{X}_i^\delta(0) \qquad \begin{array}{l} i = 1, 2, \ldots, 8 \\ \delta = 1, 2, \ldots, 4 \end{array}$$

and

$$X_{n+1}(0) \leqslant \overline{X_{n+1}(0)}$$

where X_i^δ = annual production of i^{th} good in δ^{th} region during 1960-61.

Table 1 gives the statistics relating $\overline{X}_i^\delta(0)$ and $\overline{X}_{n+1}(0)$, *i.e.*, the productive capacities of these activities on April 1, 1960, and their statistical estimation is discussed in Appendix A. It is, further, assumed that each of the four regions have "unlimited" supplies of labor force during the period of planning so that all planning problems due to labor constraints can be totally ignored.[4]

For the exogenous sectors, the levels of outputs at each of the four time points (1960-61, 1965-66, 1970-71, and 1975-76) are specified. The estimates for 1960-61 are given in Table 2 and the methods of estimation are discussed in Appendix A. The output levels for the successive years are obtained by applying certain rates of growth on initial outputs. These growth rates are 4 per cent for agricultural and allied activities, 5 per cent for small-scale manufacturing and service sectors, and for the other exogenous large-scale manufacturing sectors two separate growth rates—namely, 5 per cent and 7 per cent—are applied to get two different sets of results for the planning model.

4. If various skill compositions of the heterogeneous labor force were taken into account, some of the regions might have required to import certain types of skilled workers; but with respect to the total labor force, each of these big regions is in abundant supply.

Distribution of Goods and Services.

For each of the eight regional activities, total available supply at a region should at least exceed the demands due to (*i*) current inputs into other endogenous sectors, (*ii*) fixed investment inputs into other endogenous sectors, (*iii*) working capital, (*iv*) current and capital inputs into the (inter-regional) transport sector, (*v*) replacement of depreciated fixed assets of the region, (*vi*) current and capital inputs into the exogenous sectors, (*vii*) household consumption, and (*viii*) government consumption. Algebraically,

$$X_i^{\delta}(t) + \sum_{\mu=1}^{5} X_i^{\mu\delta}(t) - \sum_{\mu=1}^{5} X_i^{\delta\mu}(t) \geqslant$$

$$\geqslant \sum_{j=1}^{8} X_{ij}^{\delta}(t) + \sum_{j=1}^{8} I_{ij}^{\delta}(t) + S_1^{\delta}(t) + X_{i,\,n+1}^{\delta}(t)$$

$$+ D_i^{\delta}(t) + E_i^{\delta}(t) + C_i^{\delta}(t) + G_i^{\delta}(t), \qquad (2)$$

where $X_i^{\delta}(t)$ = output of i^{th} good in the δ^{th} region at time t;

$X_i^{\delta\mu}(t)$ = transporation of i^{th} good from δ^{th} to the μ^{th} region at time t;

$X_i^{\delta\delta} \equiv 0$.

The 5th region is the rest of the world so that $X_i^{\delta 5}(t)$ and $X_i^{5\delta}(t)$ are exports and imports respectively.

The seven additive terms on the right hand side of the inequality (2) are the seven categories of demands enumerated above.

Production Functions

Each activity in each region is subject to a given fixed coefficient Leontief technology for the entire planning period, so that

$$X_{ij}^{\delta}(t) = a_{ij}^{\delta} \quad X^{\delta}(t) \qquad (3)$$

$$I_{ij}^{\delta}(t) = b_{ij}^{\delta}\, \Delta X_j^{\delta}(t) \tag{4}$$

$$X_i^{\delta}(t+1) \leqslant X_i^{\delta}(t) + \Delta X_j^{\delta}(t) \tag{5}$$

$$i, j = 1, 2, \ldots, 8$$
$$\delta = 1, 2, \ldots, 4$$

The equation (3) specifies the Leontief input-output relationship; equation (4) specifies the capital-output relationships with fixed coefficient and the equation (5) specifies the capacity creation in the various sectors in the dynamic system. The inequalities in the capital formation relations (instead of strict equality) are to make allowance for the idle capacities. Table 3 presents the input-output coefficients for the various sectors, and their estimation procedure is discussed in Appendix B. The capital coefficients, however, present some additional difficulties. All the output variables in this model are measured as flow for the year, whereas the interval between two points of time is five years, so that ΔX in (5) refers to increase in output over five years. Now if the $I_{ij}^{\delta}(t)$ deliveries for any year are to provide the entire dynamic chains for the intertemporal changes in outputs over five year periods, some drastically simplifying assumptions about the time patterns of investments and outputs are called for.

Our taking of five years as a unit of time could be unhazardous if the nature of investment activities were such that nothing happens in the infra-margin and all investments mature exactly after five years (or any multiple of five years). But these "gestation lags" in most of the activities are admittedly much below five years, though until now not much empirical work has been done to estimate these lag structures. Now if these lags are taken to be less than five years (*i.e.*, less than the unit of time interval in this exercise) some assumptions have to be made about the time pattern of the increase in the outputs, which after all, the model attempts to determine optimally. In this exercise, a combination of a gestation lag of one year and a first approximation of a five per cent annual rate of growth for each sector is assumed. So that if the technologically determined capital coefficients (with one year lag) are β_{ij}^{δ}, then the modified coefficients b_{ij}^{δ} to be used for the computation can be taken as

$$b_{ij}^{8} = \beta_{ij}^{8}\left[1 + \frac{1}{1+\gamma} + \frac{1}{(1+\gamma)^2} + \frac{1}{(1+\gamma)^3} + \frac{1}{(1+\gamma)^4}\right],$$

where γ = assumed rate of growth of the sector during the time interval. For $\gamma = .05$, $b_{ij}^{8} = 0.18\ \beta_{ij}^{8}$ (approx.).

However, the gestation lags for most of these sectors would be higher than one year. Again the growth rates for these sectors are again likely to be higher than those of the other sectors, because of their low base levels and the expected high import substitution in these sectors, so that on the balance the approximation may not be altogether unrealistic.

Tables 4 present the estimated capital coefficients and the estimating procedures are discussed in Appendix B.

Working Capital

Normally three different sources of demands are assumed to work on the level of the stock of any output,[5] namely stocks of raw materials, stocks of semi-finished goods and stocks of finished goods. The first is determined by the activity levels of various industries using it as current inputs and hence the form of the demand equations due to increase in stock holding should be similar to those of fixed investments in (4). The second part is rather indeterminate because the nature of any half-finished product is unidentifiable. If it is identified as the same good as the finished product, its demand can be related to its own output level. The third categories of stocks are probably related to the level of the final demands of the good. The statistics relating to these complex inter-relations are meagre. Anyway, in this exercise the demand for a good due to changes in circulating stocks is taken as

$$S_i^{8}(t) = s_i\, X_i^{8}(t), \qquad (6)$$

where s_i coefficients (presented in Table 5) are computed from the estimated quantities of the various goods going into inventory accumulation.

5. See A. K. Sen, "Working Capital in The Indian Economy: A Conceptual Framework and Some Estimates," in P. N. Rosenstein-Rodan, ed., *Pricing and Fiscal Policies*. M. I. T. Press, 1964.

Besides, computational simplicity, the only excuse for such an over-simplified demand relationship, is that it limits to a minimum the number of not too reliable parameters.

Depreciation

Normally, three different types of assumptions are made to explain severally or collectively the depreciation of capital stocks: (*i*) purely time-dependent depreciation, the simplest version of which is "exponential decay", (*ii*) "user's cost" depreciation where it depends on the level of output, and (*iii*) "one-horse shay" depreciation, *i.e.*, capital stocks work at full capacity during the entire lifetime, at the end of which it competely collapses. In this exercise the third assumption is chosen as the only explanation of depreciation. Therefore, the demand for the replacement of depreciated capital stock at a particular year depends on investment activities of θ years ago, where θ is the expected life of capital. Hence, if the perod of planning is not longer than the average life of capital stock, then the replacement demands essentially depend on the rate of capital accumulation in the pre-planning period. In our case the planning period is fifteen years and the economic life of plants and equipment in India is in most cases as much as that or even longer. Therefore, the replacement demand for the planning period is exogenously estimated by applying on the estimated replacement requirements in 1960-61 the average growth rate of the economy during 1950-60, which was 3.5 per cent. The base year's replacement demands for the products of the endogenous sectors were taken from the national aggregates of these demands estimated in the multisectoral planning model for India by R. S. Eckaus and regional compositions are worked out by dividing the national aggregates in proportion to the share of national income originating from the various regions.

This is admittedly a very simple device, but in this area known economic facts (and more so available statistics) are so meagre that any attempt at complicated estimating procedures would not have been a very fruitful exercise.

Furthermore, the demand for replacement is exogenously specified, *i.e.*, it is assumed that at the end of its life every bit of capital stock will be fully replaced. This assumption rules out the possibility of planned retirement of certain productive capacities.

Table 6 presents the exogenously specified replacement demands: $D_i^{\delta}(t)$.

Demand Due to the Exogenous Sectors

$E_i^\delta(t)$ is the demand for the output of the i^{th} sector in δ^{th} region at time t due to the current and capital inputs in all the exogenous sectors in the same region and at the same time. So

$$E_i^\delta(t) = \sum_K a_{iK}^\delta X_K^\delta(t) + \sum_K r_K \beta_{iK}^\delta X_K(t), \tag{7}$$

where a_{iK}^δ and β_{iK}^δ are the usual fixed coefficient input and capital coefficients of K^{th} industry (exogenous) in δ^{th} region and r_K is the exogenously specified annual growth rates in $X_K^\delta(t)$.

Household and Government Consumption

In the absence of any detailed regional income studies in India, the regional consumption levels, both household and government, are obtained by dividing the national consumption according to the size of the population in each region.

For the purposes of this exercise a growth rate of 3 per cent per annum is specified for each of these consumption items $C_i^\delta(t)$ and $G_i^\delta(t)$[6]. Table 7 gives the specified time pattern of $C_i^\delta(t)$ and $G_i^\delta(t)$.

Transportation

Inter-regional transportation presents some very difficult problems. One is that when railways, road transports, coastal and inland shipping, airways, animals and animal-driven carts, pipelines, transmission cables, etc. form a complex network moving goods and people from place to place with complicated processes of loading, unloading and transshipment, how should an activity be defined which is only engaged in moving goods and people from one region to another as we have defined them? Secondly, how should one specify the production function for such an activity?

6. Alternative consumption patterns could have been tried, but that would not add much to the main conclusions of this model.

If one looks into the pattern of freight traffic in India, one will find that more than 90 per cent of long distance goods movement is carried on by railways[7]. Whether such a pattern is optimal for the economy is a different question, which we have chosen to leave outside the scope of the present work. However, if railways do perform (and are expected to perform) the large bulk of inter-regional transportation, then it can be taken to represent our inter-regional transport activity. Even then, as we have defined our regions as rather large areas, a lot of intra-regional transportation is also carried on by the railways.

What has been done in this exercise is as follows : In the base year one half of the national railway capacity[8] is taken to provide inter-regional transport capacity. All other modes of transportation and the other half of railways are taken to be devoted entirely to intra-regional transportation ; and their levels and rates of growth are specified exogenously. Again in 1960-61 about 65 per cent of the inter-regional transport capacities were engaged in passenger traffic and in movement of goods which are exogenous in our model[9]. Accordingly, that much of the output in the base year was assumed to go to satisfy exogenous demands. The growth of this exogenous demand is specified from the outside.

Therefore, the demand for the inter-regional transportation is written as follows :

$$X_{n+1}(t) \geq \sum_{i,\delta,\mu} \tau_i^{\delta\mu} \cdot X_i^{\delta\mu}(t) + E_{n+1}(t), \tag{8}$$

where the matrices of transport demand coefficients $\tau_i^{\delta\mu}$ are presented in Table 8 and their method of estimation discussed in Appendix B.

The production function for this sector is specified as the fixed coefficient Leontief technology for railways and the inputs into transportation are assumed to be moved costlessly from any of the regional supplies so that

$$\sum_{\delta} X^{\delta}_{i,\,n+1}(t) \geq a_{i,\,n+1} \cdot X_{n+1}(t) + b_{i,\,n+1} \Delta X_{n+1}(t). \tag{9}$$

7. See Lefeber and Datta-Chaudhuri, "Transportation Policy in India," in P. N. Rosenstein-Rodan, ed., *Pricing and Fiscal Policies*, M. I. T. Press, 1964.

8. Capacity in the base year has been estimated by the outputs in 1960-61, in all sectors.

9. See Lefeber and Datta-Chaudhuri, *op. cit.*

The input and capital coefficient vectors $a_{i,n+1}$ and $b_{i,n+1}$ are presented with those of other sectors in Tables 3 and 5. Capacity creation in transport sector is specified as:

$$X_{n+1}(t+1) \leqslant X_{n+1}(t) + \Delta X_{n+1}(t). \tag{10}$$

Foreign Trade

Since this is essentially a partial equilibrium model, it is difficult to build into it the framework of a complete equilibrium of India's foreign trade, particularly because more than 80 per cent of India's current exports come from the sectors which are considered exogenous in this exercise, namely, jute and cotton textiles, tea, oilseeds, leather, etc. But the quantitatively important items of import are machinery and other metal products. The policy of limiting imports into these groups of investment and intermediate goods has not been successful so far because of the failure of agriculture and allied activities to come up with planned levels of outputs. As a result, a substantial proportion of foreign exchange earnings and foreign aid and loan go into the import of food grains, cotton fibers, etc. In this model, a 4 per cent growth rate has been stipulated for agriculture and the required quantities of current and capital inputs have been allotted for the purpose. This rate of growth, if it is forthcoming, can free the economy from the necessities of imports. The other products of the exogenous sectors which are also currently imported are fertilizers and chemical products where again exogenous growths are stipulated.

So this model requires some mechanism of choosing the quantities for export of the products of the endogenous sectors and also the imports of these goods.

The export items of these sectors are projected into the future by the geometric extrapolation of these time series corresponding to the 2nd Five Year Plan period (1955-60). Table 9 shows the projected time series from 1960-61 to 1970-71. It is left to the model to determine optimally the regions from which the specified export quantities are to be procured; so that

$$\sum_{\delta} X_i^{\delta,5}(t) \geqslant \overline{\overline{X}}{}_i^5(t). \tag{11}$$

As regards imports, it is left to the model to decide optimally what to import and when, given a time profile of foreign exchange to be used for buying these goods from abroad. As a matter of fact, the model is solved for four different sets of such foreign exchange availabilities. As any student of the structure of Indian economy should expect, availability of foreign exchange turns out to be a crucial factor in determining the feasibilities of various growth programmes.

The rationale of this procedure is as follows: Agriculture is subject to various uncertainties and to what extent its growth can be engineered by investment planning alone is a debatable issue. And it is commonly believed that the major Indian export goods face a relatively inelastic market abroad. So, exports can be projected exogenously. Taking into account these expected export earnings and possible amounts of foreign aids and loans, an investment planning model can determine an optimum import pattern (and an optimal pattern of import substitution) in those sectors where technological coefficients are less uncertain. If, in spite of the input allocations agricultural sectors in some periods do not come out with expected outputs, the result would be higher dependence on external sources, failing which serious food shortages, famines, etc. Strictly speaking, one should take into account the so-called interdependence between agriculture and industries, *i.e.*, failure in agriculture may pull back any process of industrialization, but like lots of other simultaneities of the economic system this one is ignored in this exercise.

So, the import demand equations are specified as

$$\sum_{i=1}^{7} \sum_{\delta} X_i^{5,\delta}(t) \leqslant \overline{A(t)}. \tag{12}$$

Electricity imports are ruled out considering the geography and politics of this part of the world; so are interregional transport services.

Absolute Advantage

In the context of a linear model, besides transport costs, the only source of possible regional specialization is absolute advantage in extractive and other natural resource-intensive activities. In determining the location patterns of metal product or power generation industries, supplies of mining products are important. What this empirical exercise essentially tries to answer is that given the sources of coal, iron ore and other minerals, and also given the patterns of transport costs and regional demands, at what stage of processing is it economical to carry out the long distance transportation. In other words, is it preferable to transport minerals and perform the metallurgical processing and fabrication at the location of demand? Or is it better only to transport metals and fabricate on the spot? Or to transport metal products only at the final stage of processing? Of course, the structure of the economy is not that neatly decomposable to make it possible to do partial analysis for the product of each industry.

However, if the regions were so defined that one could rule out the possibilities of mining certain products from some regions, but make them producible elsewhere with appropriate Leontief technologies (with or without some upper limit to these levels of production) then the question of "absolute advantage" could be taken care of adequately. But to keep the size of the computation low, we have divided the entire country into only four regions. It is true that most of the coal and iron ores in India are mined in the Bengal-Bihar-Orissa belt, and geological surveys do not show any such comparable mining deposits elsewhere; but small quantities of these minerals are produced in other regions too. If no limits are put on the mining possibilities in those regions, any efficient transport programme would call for large expansion in these mining areas to minimize haulage unless, of course, mining became economically prohibitive there. If competent geological surveys show the size of known mineral reserves in various regions and various feasible time patterns of extracting them, then that would be a good way of putting constraints on these activities.

As it is, no such expert geological analysis is available in required details. So the following rather simple constraints are imposed on the production of the three mining sectors : the output of any mineral in any region (other than the eastern region) as a ratio of that in the eastern region should not exceed the observed ratio in the base year. Algebraically,

$$X_i^{\delta}(t) \leqslant a_i^{\delta} X_i^1(t), \qquad (13)$$

where

$$a_i^{\delta} = \overline{X_i^{\delta}}(0)/\overline{X_i^1}(0)$$

$$i = 1, 2, 3$$

$$\delta = 2, 3, 4$$

Objective Function

Once the initial conditions, the planning period, the time pattern of the various items of final demand and the levels of foreign trade are specified, the only parameters that remain to close the system are the terminal conditions. If the levels of terminal outputs $X_i^s(T)$ were specified arbitrarily one could perform a consistency exercise to see if all these exogenous specifications are consistent with one another given the technological coefficients.

However, in this exercise the terminal outputs form the objective function of this optimization model. The model chooses to reach a maximum level of a composite commodity which is formed with fixed composition of the outputs of the nine endogenous sectors at the terminal period, where the regional distribution of these outputs are left for the model to determine optimally. The composite commodity, Y, is defined as follows:

$$Y = \text{Min}\left[\frac{\sum_s X_1^s(T)}{\gamma_1}, \ldots, \frac{\sum_s X_8^s}{r_8} -, \frac{X_{n+1}}{r_{n+1}}\right].$$

Here, of course, comes the question of the rationale of these coefficients of composition, r_i's. The composition of any period's output is only optimal with respect to the final demands at that period and those in the future ahead.

No attempt will be made here to justify the particular set of r_i's used in this model. These are borrowed from the terminal composition of a long term multisectoral planning model for India worked out by Alan S. Manne and Ashok Rudra.[10]

However, it should be mentioned that for a planning model like the present one involving only these eight sectors, small misspecifications in the terminal composition will not prove to be crucial. Because a large part of the total domestic demand for these products are currently met by imports, and given the conditions of foreign trade, this planning period is characterized by rapid programmes of import substitution in these sectors.

10. "Studies in the Structure of Indian Economy," (mimeographed, Indian Statistical Institute, New Delhi, August 1964).

Moreover, it is generally believed that export markets for the products of these sectors are fairly elastic. So, any small misspecification in the output composition for these sectors are correctible via foreign trade.

Besides, the essential purpose of this exercise is to find the comparative advantages of various regions given the geographical distribution of minerals and the pattern of transport costs. Any changes in the composition of final output would not alter the regional pattern of comparative advantages.

Moreover, this is essentially a three period model, so that demand and distribution conditions are specified for 1960-61, 1965-66 and 1970-71. The terminal conditions are in terms of the 1975-76 outputs, for which the proper distribution conditions of the type (2) are not specified. Hence, the capacities created between 1970-71 and 1975-76 are only determined by cost considerations and not by demands. So, in interpreting the results of this model relatively little emphasis should be put on the capacities created between 1970-71 and 1975-76.

Now we have a well-defined Linear Programming problem where

Maximize Y

subject to

$$\sum_{\delta=1}^{4} X_i^{\delta}(T) \geqslant r_i Y \qquad i = 1, \ldots, 8$$

$$X_{n+1}(T) \geqslant r_{n+1} Y \tag{14}$$

and all the constraints (1) to (13). In addition, we specify, as usual, the non-negativity condition on each of the variables.

III

Results

This Linear Programming Model was solved for two sets of alternative specifications of the exogenous parameters. In every case, houshold and government consumptions were allowed to grow at the rate of 3 per cent per annum over the given levels of each good in every region in 1960-61. Only one exogenously specified time profile of the export demand for the products of the endogenous sectors are taken. The composition of the terminal output levels also remains the same ; although, if due to the requirement of the fixed composition of the terminal outputs, some of the already existing productive capacities are not used, then in the presentation of the final outputs (capacities) these terminal-condition-determined idle capacities are ignored. So, the outputs in 1975-76 are to be interpreted as productive capacities in that year. But the model has been solved for certain alternative values of the other two arbitrary specifications ; namely, the growth rates of the exogenous sectors, and the availabilities of foreign exchange in different periods of time. As regards the growth rates of the exogenous sectors, agriculture is everywhere specified to be growing at the rate of 4 per cent, because this rate of growth of Indian agriculture is believed to be adequate, if forthcoming, to satisfy domestic demands for food grains and to sustain at least a 7 per cent rate of growth for the whole economy ;[1] small-scale industries, trade and services sectors are specified to be growing at the rate of 5 per cent per annum ; for the other exogenous large-scale industrial sectors and for the exogenous demand for the inter-regional transportation, two different rates of growth are used : (*i*) 5 per cent and (*ii*) 7 per cent per annum.

As regards the availabilities of foreign exchanges for meeting the import bills for the products of the endogenous sectors, six different sets (of three periods' supply figure for 1960-61, 1965-66 and 1970-71 each) of foreign exchange availabilities are assumed in this exercise. These are (793.95, 885.62, 1008.45), (893.95, 885.62, 1008.45), (893.95, 985.65, 1008.45), (893.95, 985.65, 1058.45), (993.95, 985.62, 1058.45) and (993.95, 1085.62, 1058.45) each measured in units of crores of rupees.[12]

In total seven sets of results are obtained. They are :

1. Exogenous growth : 5 p. c. with import (793.95, 885.62, 1008.45) ... no feasible solution
2. Exogenous growth : 5 p. c. with import (893.95, 885.62, 1008.45) ... Optimum Solution I
3. Exogenous growth : 5 p. c. with import (893.93, 985.62, 1008.45) ... Optimum Solution II

11. See "Notes on Perspective of Development, 1960-61 to 1975-76" by Perspective Planning Division, Planning Commission, Government of India, New Delhi, 1963.

12. 1 crore = 10 millions Foreign exchange is measured in base-year exchange rate. The Indian export earnings in 1960-61 were Rs. 643.95 crores. According to projection of PPD (ibid.) these would come to Rs. 785.62 crores in 1965-66 and Rs. 958.45 crores in 1970-71. Our figures were obtained by adding alternative sets of possible round numbers to this set. For the purposes of this exercise these are strictly exogenous and no attempt is made here to test the feasibilities of these projections.

4. Exogenous growth : 5 p. c. with imports (893.95, 985.62, 1058.45) ... Optimum Solution III
5. Exogenous growth : 7. p. c. with imports (893.95, 985.62, 1058.45) ... no feasible solution
6. Exogenous growth : 7 p. c. with imports (993.95, 985.62, 1058.45) ... Optimum Solution IV
7. Exogenous growth : 7 p. c. with imports (993.95, 1085.62, 1058.45) ... Optimum Solution V

The levels of outputs of the different sectors in different regions and of the inter-regional transport sector are presented in Tables 10, 11, 12, 13 and 14 for the five optimal solutions respectively.

These five tables summarize the results we are chiefly interested in : given the conditions of absolute advantages in mining and the structure of transport costs, how the capital formation in different sectors is to be geographically distributed. As can be seen in these five tables, the levels of the terminal capacities vary with the exogenous specifications particularly with the availabilities of foreign exchange. It is not surprising to find that with less than Rs. 800 crores of machinery, equipment and other metal products imports in 1960-61, the economy could not embark on a program of a 3 per cent growth of consumption, 4 per cent growth of agriculture and a 5 per cent growth of other manufacturing. If a 7 per cent rate of growth in other manufacturing sectors were aimed at, even Rs. 900 crores of these importables in 1960-61, would be insufficient.

The results shown in Tables 10, 11, 12, 13 and 14 show a rather clear qualitative picture about the efficient geographical distribution of new capacities to be formed in the different sectors considered here. The table below lists the cases of positive capacity creations called for in the five different optimum solutions worked out here. The entry of a number in the table indicates that in the optimum solution numbered thus, in the particular sector of the particular region additional capacity is created during the time interval.

In interpreting these qualitative results one should be careful about the interpretation of the capital formations in the first and in the last period. The first period, because the given intial distributions play a large part in determining the pattern.

Regional Distributions of Capital Formation In Different 5 Year Periods

	1960-61 to 1965-66	*1965-66 to 1970-71*	*1970-71 to 1975-76*
Zone I			
1. Coal		2,3,4,5	2,3,4,5
2. Iron Ore		1,2,3,4,5	1,2,3,4,5
5. Other Minerals			1.2,3,4,5
4. Iron & Steel		1,2,3.4,5	1,2,3.4,5
5. Non-Ferrous Metal	1, 4,5	1,2,3,4,5	
6. Machinery	1.2,3,4,5	1,2,3,4,5	
7: Transport Equipment	1,2.3.4,5	1,2,3,4.5	2,3,4,5
8. Electricity	1,2,3,4,5	1,2.3,4.5	2,3,4,5
Zone II			
1. Coal		2,3,4,5	
2. Iron Ore			
3. Other Minerals			
4. Iron & Steel			
5. Non-Ferrous Metal			
6. Machinery			
7. Transport Equipment	1,2,3.4,5		
8. Electricity	1,2.3,4,5	1,2,3,4,5	
Zone III			
1. Coal		2,3,4,5	
2. Iron Ore			
3. Other Minerals			
4. Iron & Steel			
5. Non-Ferrous Metal		3.4,5	
6. Machinery	1,2,3,4,5	1,2,3,4,5	
7. Transport Equipment	1,2,3,4,5	1,2,3,4,5	
8. Electricity	1,2,3.4,5	1,2.3,4.5	
Zone IV			
1. Coal		2,3,4,5	
2. Iron Ore			
3. Other Minerals			
4. Iron & Steel			
5. Non-Ferrous Metal	1, 4,	1,2,3,4,5	
6. Machinery	1,2,3,4,5	1,2.3,4,5	
7. Transport Equipment	1,2,3,4,5	1.2,3,4,5	
8. Electricity	4,	1,2,3,4,5	
Transport	4,5	2.3,4,5	2.3,4,5

In a linear programming model with five years between the first point and the next point in time, the system is not given any choice about a quick adjustability of any unbalanced production structure it starts with. In our situation, the plan begins with serious shortages of electricity in the country, severely so in at least three regions given the high cost of transporting electricity. So, the model calls for a capacity creation in electricity sectors. Other minerals, Iron and Steel, Machinery and Transport Equipment are all in short supply. Given only one import demand equation, the optimization process chooses to correct the more severe of these scarcities, namely those of machinery and transport equipment. It is only in the next possible opportunity—which comes only after five years in this model—a more balanced process of capital formation can begin.

Similarly, the distribution of capacity creation in the last period are subject to certain artificial rigidities imposed on the model; namely, (*a*) the absence of proper demand conditions on the terminal outputs and (*b*) the composition of final outputs. So, capacity creation during that period is determined by production cost alone and not by any real constraints due to demands, and is further subject to the specified constraints of composition.

But the second period's new capacity distribution does reflect more realistically the long run comparative advantages of the various regions. Here again one should say that it is so subject only to those aspects of reality encompassed in this essentially investment planning model. However, the results clearly indicate the following:

(*i*) It is inefficient to transport coal, iron ore, etc. to set up an iron and steel industry in the consuming region. Iron and steel industries should be near the sources of mining.

(*ii*) For distant regions it is efficient to transport metals and fabricate machinery and equipments on the spot (as is done in Regions III and IV); but for Region II, it is cheaper to import both metals and fabricated machinery.

The results also indicate that it is uneconomical to build up capacities in the "Other Mining" sector in India. This "Other Mining" sector is an aggregate of various metallic ores and crude petroleum. If the exercise were more disaggregative, it could have been possible to isolate the products which are, according to the production coefficients used in the model, shown to be against India's comparative advantage. However, the signal given by this optimality exercise is that the costs of production in "Other Mining" relegate it to an item of lowest priority in the general scheme of import substitution for the fifteen year plan.

TABLE 1

Capacities in Endogenous Sectors in 1960-61

	(In Rs. Crores)
Region I	
Coal	86.59
Iron Ore	5.72
Other Minerals	16.89
Iron & Steel	153.14
Non-Ferrous Metals	18.86
Machinery	176.03
Transport Equipments	64.02
Electricity	33.93
Region II	
Coal	13.80
Iron Ore	1.66
Other Minerals	13.37
Iron & Steel	17.62
Non-Ferrous Metals	3.58
Machinery	47.25
Transport Equipments	42.43
Electricity	18.67
Region III	
Coal	1.69
Iron Ore	0.63
Other Minerals	4.31
Iron & Steel	21.80
Non-Ferrous Metals	3.96
Machinery	95.76
Transport Equipments	54.88
Electricity	4.26
Region IV	
Coal	6.71
Iron Ore	1.01
Other Minerals	11.10
Iron & Steel	50.09
Non-Ferrous Metals	12.37
Machinery	151.42
Transport Equipments	71.16
Electricity	45.74

TABLE 2-A

Outputs of Selected Large Scale Industries in 1960-61

(In Rs. Crores)

Region I	
Fertilizers	12.94
Other Chemicals	47.50
Textiles (cotton, jute, silk, etc.)	199.34
Cement	11.82
Sugar	26.61
Paper & Paper Board	32.17
Leather & Rubber Products	38.62
Construction	315.10
Region II	
Fertilizers	0.24
Other Chemicals	21.28
Textiles	149.57
Cement	19.49
Sugar	104.76
Paper and Paper Board	8.77
Leather & Rubber Products	7.42
Construction	664.70
Region II I	
Fertilizers	7.72
Other Chemicals	28.35
Textiles	156.39
Cement	21.48
Sugar	27.20
Paper and Paper Board	11.52
Leather & Rubber Products	14.5
Construction	462.10
Region IV	
Fertilizers	1.95
Other Chemicals	114.56
Textiles	438.90
Cement	8.40
Sugar	32.80
Paper and Paper Board	9.96
Leather & Rubber Products	24.06
Construction	353.90

TABLE 2-B

Value Added by the Other Exogenous Sectors in 1960-61

(In Rs. Crores)

Region I	
Agriculture & Allied Activities	1767.47
Small Scale Industries	256.01
Miscellaneous Large Scale Industries	93.15
Railways	79.66
Other Transport	45.40
Communication & Warehousing	21.01
Trade	438.08
Housing	83.78
Other Services	460.94
Region II	
Agriculture	2997.12
Small Scale Industries	323.23
Miscellaneous Large Scale Industries	50.89
Railways	92.83
Other Transport	74.95
Communication & Warehousing	30.63
Trade	428.28
Housing	122.55
Other Services	637.26
Region III	
Agriculture	1799.92
Small Scale Industries	262.87
Miscellaneous Large Scale Industries	44.29
Railways	43.44
Other Transport	73.65
Communication & Warehousing	22.64
Trade	359.22
Housing	98.75
Other Services	535.88
Region IV	
Agriculture	1016.60
Small Scale Industries	219.29
Miscellaneous Large Scale Industries	54.84
Railways	59.98
Other Transport	54.84
Communication & Warehousing	24.79
Trade	447.43
Housing	72.97
Other Services	393.89

TABLE 3-A

Input-Output Coefficients for the Endogenous Sectors

Receiving Sectors								Region I	Region II	Region III	Region IV	
Supplying Sectors	1	2	3	4	5	6	7	8	8	8	8	9
1. Coal	.034	.001	.001	.034	.012	.003	.002	.0114	.0094	.0101	.0094	.045
2. Iron Ore				.019								
3. Other Minerals	.012	.003	.003	.034	.177	.006	.009	.0023	.0019	.0020	.0019	.011
4. Iron & Steel	.001		.002	.210		.261	.107					.033
5. Non-Ferrous Metals	.002			.046	.235	.062	.017					
6. Machinery	.029	.025		.016	.010	.025	.008	.0034	.0028	.0030	.0028	.022
7. Transport Equipment	.006		.001				.003					
8. Electricity	.005	.018	.001	.036	.147	.005	.014	.0023	.0019	.0020	.0019	.027
9. Railways												

Note : Except for Electricity, all other sectors are taken to have the same input-output coefficients.

TABLE 3-B

Input-Output Coefficients for Selected Large-Scale Manufacturing Sectors

(only the inputs from endogenous sectors)

Receiving Sectors			Region I	Region II	Region III	Region IV		Region I	Region II	Region III	Region IV			
Supplying Sectors	*a*	*b*	*c*	*c*	*c*	*c*	*d*	*e*	*e*	*e*	*e*	*f*	*g*	*h*
1. Coal	.027	.011	.008	.008	.007	.006	.100	.002	.002	.002	.002	.007	.002	
2. Iron Ore														
3. Other Minerals	.033	.050	.006	.007	.006	.005	.114	.007	.006	.005	.006	.013	.004	.018
4. Iron & Steel														.080
5. Non-Ferrous Metals		.011												.007
6. Machinery		.006	.001	.001	.001	.001		.008	.007	.006	.007	.027	.009	.020
7. Transport Equipment														
8. Electricity	.167	.039	.029	.029	.028	.025	.058	.001	.001	.001	.001	.010	.001	—

Note : Exogenous Sectors : (*a*) Fertilizer, (*b*) Other Chemicals, (*c*) Textiles, (*d*) Cement, (*e*) Sugar, (*f*) Paper and Paper Board, (*g*) Leather & Rubber, (*h*) Construction.

TABLE 3-C

Input—"Value Added" Ratios for Other Exogenous Sectors

(Inputs from Endogenous Sectors Only)

Receiving Sectors / *Supplying Sectors*	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
1. Coal	.00005	.01	.035	.0701	.0307	.0006	.0019		.0015
2. Iron Ore									
3. Other Minerals	.00087	.015	.08	.016	.150	.024	.0022	.0016	.0040
4. Iron & Steel		.0103	.076	.049	.0114	.024		.0053	
5. Non-Ferrous Metals		.0136	.034		.005	.022			.0030
6. Machinery	.00073			.0183			.0023		
7. Transport Equipment					.113				
8. Electricity		.007	.0102	.038	.0012	.0008	.0052		.0116

Note : (*a*) Agriculture, (*b*) Small Industries, (*c*) Miscellaneous Large Industry, (*d*) Railways, (*e*) Other Transports, (*f*) Communications, (*g*) Trade, (*h*) Housing. (*i*) Other Services.

TABLE 4-A

Fixed Capital-Value Added Ratios in Other Exogenous Sectors

Receiving Sectors	*Region* I	II	III	IV								
Supplying Sectors	*a*	*a*	*a*	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
Iron and Steel							0.04					
Machinery	0.22	0.16	0.15	0.22	0.26	1.26	0.48	0.40	0.68	0.03		0.01
Transport Equipment						0.05	2.85	2.35	0.41	0.02		0.02

Note: 1. Coefficients relating only to the endogenous sectors are shown here.

2. (*a*) Agriculture, (*b*) Small-Scale Industries, (*c*) Miscellaneous Large Industries, (*d*) Railways, (*e*) Other Transport, (*f*) Communication, (*g*) Trade, (*h*) Housing, (*i*) Other Services.

TABLE 4-B

Fixed Capital-Output Coefficients for Endogenous Sectors

Receiving Sector / *Supplying Sector*	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
Iron and Steel				0.06		0.04		0.13	0.022
Non-Ferrous Metals					0.04				
Machinery	1.48	1.56	2.53	0.93	0.14	0.25	0.60	2.96	0.32
Transport Equipment	0.10	0.10	0.14	0.04	0.11				2.00

Note : (*a*) Coal, (*b*) Iron Ore, (*c*) Other Minerals, (*d*) Iron & Steel, (*e*) Non-Ferrous Metals, (*f*) Machinery, (*g*) Transport Equipment, (*h*) Electricity, (*i*) Transport.

TABLE 4-C

Fixed Capital-Output Coefficients for Selected Large Scale Industries

Receiving Sector			*Region* I	II	III	IV					
Supplying Sector	*a*	*b*	*c*	*c*	*c*	*c*	*d*	*e*	*f*	*g*	*h*
Iron & Steel	0.25										
Non-Ferrous Metals		0.05									
Machinery	0.35	0.67	0.25	0.32	0.37	0.29	1.30	0.80	0.95	0.19	0.3
Transport Equipment			0.01	0.01	0.01	0.01	0.02	0.04	0.01		0.01

Note: 1. Only the coefficients relating to the endogenous supplying sectors are considered.

2. (*a*) Fertilizer, (*b*) Other Chemicals, (*c*) Textiles, (*d*) Cement, (*e*) Sugar, (*f*) Paper and Paper Board, (*g*) Leather and Rubber, (*h*) Construction.

TABLE 5

Inventory-Output Ratios in 1960-61

Coal	0.0336
Iron Ore	0.0308
Other Minerals	0.0308
Iron & Steel	0.0558
Non-Ferrous Metals	0.0771
Machinery	0.0609
Transport Equipment	0.0186
Electricity	—

TABLE 6

Demands Due to Replacements of Depreciated Capital Stocks

(In Rs. Crores)

Sector	*1960-61*	*1965-66*	*1970-71*
Region I			
Iron & Steel	1.847	2.197	2.615
Non-Ferrous Metals	0.127	0.151	0.179
Machinery	45.952	54.682	65.068
Transport Equipment	37 997	45.216	53.803
Region II			
Iron & Steel	2.571	3.059	3.640
Non-Ferrous Metals	0.177	0.210	0.250
Machinery	63.957	76.108	90.563
Transport Equipment	52.885	62.933	74.885
Region III			
Iron & Steel	1.364	1.623	1.931
Non-Ferrous Metals	0.094	0.111	0.133
Machinery	33.948	40.398	48.070
Transport Equipment	28.071	33.404	39.748
Region IV			
Iron & Steel	1.756	2.089	2.486
Non-Ferrous Metals	0.121	0.143	0.171
Machinery	43.701	52.004	61.880
Transport Equipment	36.135	43.000	51.167

Note : These refer to the endogenous sectors only,

TABLE 7
Household and Government Consumption Levels in 1960-61

(In Rs. Crores)

Sector	Household	Government
Region I		
Coal	1.55	0.12
Iron Ore		
Other Minerals	8.97	0.35
Iron & Steel		
Non-Ferrous Metals		
Machinery		
Transport Equipment	9.97	11.67
Electricity	2.82	1.20
Region II		
Coal	2.15	0.17
Iron Ore		
Other Minerals	12.46	0.48
Iron & Steel		
Non-Ferrous Metals		
Machinery		
Transport Equipment	13.84	16.21
Electricity	3.92	1.66
Region III		
Coal	0.84	0.06
Iron Ore		
Other Minerals	4.86	0.19
Iron & Steel		
Non-Ferrous Metals		
Machinery		
Transport Equipment	5.40	6.32
Electricity	21.12	0.65
Region IV		
Coal	1.54	0.12
Iron Ore		
Other Minerals	8.89	0.34
Iron & Steel		
Non-Ferrous Metals		
Machinery		
Transport Equipment	9.88	11.58
Electricity	2.80	1.19

TABLE 8

Unit Transport Costs

		I	II	III	IV
Coal	I	0	.43	.75	.65
	II		0	.43	.65
	III			0	.43
	IV				0
Iron Ore	I	0	.45	.76	.66
	II		0	.45	.66
	III			0	.45
	IV				0
Oiher Minerals	I	0	.45	.76	.66
	II		0	.45	.66
	III			0	.45
	IV				0
Iron & Steel	I	0	.04	.07	.07
	II		0	.04	.07
	III			0	.04
	IV				0
Non-Ferrous Metals	I	0	.01	.02	.02
	II		0	.01	.02
	III			0	.01
	IV				0
Machinery	I	0	.01	.02	.02
	II		0	.01	.02
	III			0	.01
	IV				0
Transport Equipment	I	0	.01	.02	.02
	II		0	.01	.02
	III			0	.01
	IV				0
Electricity	I	0	1.80	3.75	2.60
	II		0	1.80	2.60
	III			0	1.80
	IV				0

Note : Each matrix is symmetric. Elements in the upper triangle only shown.

An element measures the amount of transport services required to move a unit of the product from the row region to the column region or vice versa.

TABLE 9

Projection of Exports from the Endogenous Sectors

(In Rs. Crores)

Sector	*1960-61*	*1965-66*	*1970-71*
Coal	1.80	1.80	1.80
Iron Ore	2.40	3.07	3.93
Other Minerals	28.50	34.77	42.41
Iron & Steel	5.00	5.80	6.72
Non-Ferrous Metals	0.20	0.23	0.26
Machinery	3.70	4.73	6.06
Transport Equipment	0.50	0.64	0.81
Electricity	—	—	—

TABLE 10

Output Levels for Optimum Solution I

(Exogenous Growth 5%, Imports : 893.95, 835.62, 1008.45)

(In Rs. Crores)

Sectors	$x_i^\delta(0)$	$_i^\delta(1)$	$x_i^\delta(2)$	$x_i^\delta(3)$
(1)	(2)	(3)	(4)	(5)
Region I				
Coal	84.1	84.1	84.1	84.1
Iron Ore	5.72	5.72	11.02	15.31
Other Minerals	16.89	16.92	16.92	373.87
Iron & Steel	153.14	153.14	378.33	471.21
Non-Ferrous Metal	0	61.08	167.50	167.50
Machinery	176.0	527.43	754.12	754.12
Transport Equipment	64.0	119.74	158.63	158.63
Electricity	33.9	48.21	88.65	88.65
Region II				
Coal	13.4	13.4	13.4	13.4
Iron Ore	0.56	0.56	0.56	0.56
Other Minerals	13.38	13.38	13.38	13.38
Iron & Steel	17.62	17.62	17.62	17.62
Non-Ferrous Metal	0	0	0	0
Machinery	47.25	47.25	47.25	47.25
Transport Equipment	42.43	138.99	138.99	138.99
Electricity	18.67	28.49	34.84	34.84
Region III				
Coal	1.60	1.60	1.60	1.60
Iron Ore	0.63	0.63	0.63	0.63
Other Minerals	4.31	4.31	4.31	4.31
Iron & Steel	21.30	21.30	21.30	21.30
Non-Ferrous Metal	0	0	0	0
Machinery	95.76	178.73	214.27	214.27
Transport Equipment	54.88	79.16	96.44	96.44
Electricity	4.26	24.60	30.81	30.81

(1)	(2)	(3)	(4)	(5)
Region IV				
Coal	6.48	6.48	6.48	6.48
Iron Ore	1.01	1.01	1.01	1.01
Other Minerals	11.10	11.10	11.10	11.10
Iron & Steel	50.09	50.09	50.09	50.09
Non-Ferrous Metal	4.66	5.56	19.43	19.43
Machinery	151.42	273.81	333.00	333.00
Transport Equipment	71.16	98.46	118.63	118.63
Electricity	45.74	45.74	51.23	51.23
Transport	227.40	227.40	271.41	271.41

TABLE 11

Output Levels for Optimum Solution II

(Exogenous Growth 5%, Imports 893.95, 985.62, 1008.45)

(In Rs. Crores)

Sectors	$X_i^\delta(0)$	$X_i^\delta(1)$	$X_i^\delta(2)$	$X_i^\delta(3)$
(1)	(2)	(3)	(4)	(5)
Region I				
Coal	82.61	82.61	97.47	242.75
Iron Ore	5.72	5.72	17.47	45.24
Other Minerals	16.90	16.90	16.90	1057.40
Iron & Steel	153.14	153.14	696.14	1422.18
Non-Ferrous Metal	0	0	253.97	253.97
Machinery	176.03	660.41	1445.23	1445.23
Transport Equipment	64.02	108.42	275.45	464.46
Electricity	33.93	39.72	118.10	356.88
Region II				
Coal	13.13	13.13	15.50	15.50
Iron Ore	0.35	0.35	0.35	0.35
Other Minerals	13.38	13.38	13.38	13.38
Iron & Steel	17.62	17.62	17.62	17.62
Non-Ferrous Metal	0.14	0	0	0
Machinery	47.25	47.25	47.25	47.25
Transport Equipment	42.43	139.03	139.03	139.03
Electricity	18.67	28.49	34.84	34.84
Region III				
Coal	1.57	1.57	1.85	1.85
Iron Ore	0.63	0.63	0.63	0.63
Other Minerals	4.31	4.31	4.31	4.31
Iron & Steel	21.30	21.30	21.30	21.30
Non-Ferrous Metal	0.87	0.87	49.50	49.50
Machinery	95.76	184.05	214.85	214.85
Transport Equipment	54.88	80.17	96.44	96.44
Electricity	4.26	24.64	38.11	38.11

(1)	(2)	(3)	(4)	(5)
Region IV				
Coal	6.36	6.36	7.51	7.51
Iron Ore	1.01	1.01	1.01	1.01
Other Minerals	11.10	11.10	11.10	11.10
Iron & Steel	50.09	50.09	50.09	50.09
Non-Ferrous Metal	3.88	3.88	66.43	66.43
Machinery	151.42	277.38	333.57	333.57
Transport Equipment	71.16	116 45	118.64	118.64
Electricity	45.74	45.74	58.16	58.16
Transport	226.16	226.16	270.48	519.47

TABLE 12

Outputs for Optimum Solution III

(Exogenous Growth 5%. Import 893.95, 985.62, 1058.45)

(In Rs. Crores)

Sectors	X_i^δ (0)	X_i^δ (1)	X_i^δ (2)	X_i^δ (3)
(1)	(2)	(3)	(4)	(5)
Region I				
Coal	82.75	82.75	96.86	257.12
Iron Ore	5.72	5.72	16.91	47.75
Other Minerals	16.90	16.90	16.90	1115.07
Iron & Steel	153.14	153.14	667.60	1502.42
Non-Ferrous Metal	0	0	259.03	259.03
Machinery	176.03	660.22	1519.09	1519.09
Transport Equipment	64.02	108 29	288.17	507.92
Electricity	33.93	39.71	118.36	382.79
Kegion II				
Coal	13.16	13.16	15.40	15.40
Iron Ore	0.35	0.35	0.35	0.35
Other Mineral	13.38	13.38	13.38	13.38
Iron & Steel	17.62	17.62	17.62	17.62
Non-Ferrous Metal	0	0	0	0
Machinery	47.25	47.25	47.25	47.25
Transport Equipment	42.43	139.03	139.03	139.03
Electricity	18.67	28.49	34.84	34.84
Region III				
Coal	1.57	1.57	1.84	1.84
Iron Ore	0.63	0.63	0.63	0.63
Other Minerals	4.31	4.31	4.31	4.31
Iron & Steel	21.30	21.30	21.30	21.30
Non-Ferrous Metal	0	0	49.50	49.50
Machinery	95.76	184.04	214.85	214.85
Transport Equipment	54.88	80.17	96.44	96.44
Electricity	4.26	24.64	38.11	38.11

(1)	(2)	(3)	(4)	(5)
Region IV				
Coal	6.37	6.37	7.46	7.46
Iron Ore	1.01	1.01	1.01	1.01
Other Minerals	11.10	11.10	11.10	11.10
Iron & Steel	50.09	50.09	50.09	50.09
Non-Ferrous Metal	4.88	3.87	66.43	66.43
Machinery	151.42	277.36	333.57	333.57
Transport Equipment	71.16	116.42	118.64	118.64
Electricity	45.74	45.74	58.16	58.16
Transport	226.26	226.26	270.52	547.05

TABLE 13
Outputs for Optimum Solution IV

(Exogenous Growth 7%, Import : 993.95, 985.62, 1058.45)

(In Rs. Crores)

Sectors	$X_i^\delta(0)$	$X_i^\delta(1)$	$X_i^\delta(2)$	$X_i^\delta(3)$
(1)	(2)	(3)	(4)	(5)
Region I				
Coal	75.94	75.94	109.38	285.81
Iron Ore	5.72	5.72	20.35	53.37
Other Minerals	16.89	16.92	16.92	1244.47
Iron & Steel	153.14	153.14	843.36	1682.47
Non-Ferrous Metal	5.04	136.96	284.39	284.39
Machinery	176.03	701.63	1635.20	1635.20
Transport Equipment	64.02	145.96	380.76	604.92
Electricity	33.93	61.92	135.16	429.61
Region II				
Coal	12.07	12.07	17.39	17.39
Iron Ore	0.35	0.35	0.35	0.35
Other Minerals	13.38	13.38	13.38	13.38
Iron & Steel	17.62	17.62	17 62	17.62
Non-Ferrous Metal	0	0	0	0
Machinery	47.25	47.25	47.25	47.25
Transport Equipment	42.43	139.20	139.20	139.20
Electricity	18.67	36.35	37.04	37.04
Region III				
Coal	1.44	1.44	2.08	2.08
Iron Ore	0.62	0.63	0.63	0.63
Other Minerals	4.31	4.31	4.31	4.31
Iron & Steel	21.30	21.30	21.30	21.30
Non-Ferrous Metal	0	0	51.38	51.38
Machinery	95.76	188.36	219.44	219.44
Transport Equipment	54.88	80.29	96.56	96.56
Electricity	4.26	25.67	41.14	41.14

(1)	(2)	(3)	(4)	(5)
Region IV				
Coal	5.85	5.85	8.42	8.42
Iron Ore	1.01	1.01	1.01	1.01
Other Minerals	11.10	11.10	11.10	11.10
Iron & Steel	50.09	50.09	50.09	50.09
Non-Ferrous Metals	0	38.76	69.07	69.07
Machinery	151.42	287.21	342.10	342.10
Transport Equipment	71.16	98.95	118.16	118.82
Electricity	45.74	46.58	64.25	64.25
Transport	227.00	261.03	363.15	608.95

TALLE 14

Outputs of Optimum Solution V

(Exogenous Growth 7%, Import : 993.95, 1085.62, 1058.45)

(In Rs. Crores)

Sectors	$X_i^{\delta}(0)$	$X_i^{\delta}(1)$	$X_i^{\delta}(2)$	$X_i^{\delta}(3)$
(1)	(2)	(3)	(4)	(5)
Region I				
Coal	75.94	75.94	124.73	438.26
Iron Ore	5.72	5.72	27.80	80.97
Other Minerals	16.89	16.92	16.92	1879.11
Iron & Steel	153.14	153.14	1222.98	2565.46
Non-Ferrous Metal	5.04	110.84	373.62	373.62
Machinery	176.03	845.87	2306.19	2306.19
Transport Equipment	64.02	151.10	415.63	1083.20
Electricity	33.93	58.87	167.43	714.72
Region II				
Coal	12.07	12.07	19.83	19.83
Iron Ore	0.34	0.34	0.34	0.34
Other Minerals	13.38	13.38	13.38	13.38
Iron & Steel	17.62	17.62	17.62	17.62
Non-Ferrous Metal	0	0	0	0
Machinery	47.25	47.25	47.25	47.25
Transport Equipment	42 43	139.25	139.25	139.25
Electricity	18,67	31.50	37.05	37.05
Region III				
Coal	1.44	1.44	2.37	2.37
Iron Ore	0.63	0 63	0.63	0.63
Other Minerals	4.31	4.31	4 31	4.31
Iron & Steel	21.30	21.30	21.30	21.30
Non-Ferrous Metal	0	0	51.38	51.38
Machinery	95.76	188.44	219.45	219.45
Transport Equipment	54.88	80.29	96.56	96.56
Electricity	4.26	25.67	167.43	167.43

(1)	(2)	(4)	(4)	(5)
Region IV				
Coal	5.85	5.85	9.60	9.60
Iron Ore	1.01	1.01	1.01	1.01
Other Minerals	11.10	11.10	11.10	11.10
Iron & Steel	50.09	50.09	50.09	50.09
Non-Ferrous Metal	0	0	69.08	69.08
Machinery	151.42	288.53	342.13	342.13
Transport Equipment	71.16	99.76	118.82	118 82
Electricity	45.74	45.74	64.26	64.26
Transpor t	227.00	261.05	362.19	912.47

Appendix A

The Statistical Basis of the Initial Conditions of the Planning Model

The required initial conditions of the model are :

(*a*) productive capacities of the endogenous sectors at the start of the planning period, *i.e.* on April 1, 1960 ; and

(*b*) outputs of the other exogenous sectors in the first year of the plan, *i.e.*, 1960-61.

Both sets of statistics used in the computation of the optimization model are presented in Tables 1 and 2.

Measuring outputs of given industries in a given year presents fewer problems compared to those faced in defining and eventually measuring "productive capacities". Assumptions of Leontief technology presupposes the concepts of capacities, *i.e.*, once that quantity of a non-substitutable factor is fixed the maximum output of that activity is also given. Even in the case of a single process of a single plant, the concept is not always realistic; because all the available facilities of a plant do not strictly correspond to a unique level of output, and the operation costs over different shifts are not constant. So, the expansion of outputs of a typical plant is accompanied by dissimilar proportion of additional material and labor inputs. When instead of a plant one is considering the productive capacity of a more or less aggregated industry of a region, the concept becomes even more dubious.

What has been assumed in this exercise is that the capacity of an industry of a region at the beginning of the planning period is estimated by the actual output in the first year of the plan, *i.e.*, 1960-61. So the Tables 1 and 2 actually refer to the estimates of production in 1960-61. Limitations of such a simplifying assumption are obvious. But in the absence of detailed usable study of capacities (or idle capacities) this seems to be the simplest and the best assumption to make. However, given the known unbalanced nature of the structure of the Indian economy at the time, these estimates somewhat understate the productive capacities of the economy. An all-round efficient resource allocation which the planning model seeks to do, will probably show a somewhat higher potentiality than our exercises actually offer, if some measure of the initial idle capacities were taken into account.

Even under these simplifying assumptions, the estimations of initial conditions do not turn out to be straightforward collection of known statistics ; because regional income (and production) statistics in India are of rather recent origin and not detailed enough for the purposes of this model.

The most comprehensive set of studies on regional income are those prepared by National Council of Applied Economic Research, New Delhi[13]. But the sectoral details, in which these estimates are presented in complete detail, are

(*a*) agriculture
(*b*) animal husbandry
(*c*) forestry
(*d*) fishery
(*e*) extractive industries (with breakdowns for ten individual mining and quarrying products)
(*f*) manufacturing industries
  (*i*) large scale industries
  (*ii*) small industries
  (*iii*) household industries
(*g*) construction
(*h*) wholesale trade
(*i*) retailed trade
(*j*) other trade
(*k*) banking and insurance
(*l*) railways
(*m*) road transport
(*n*) other transport
(*o*) storage and warehousing
(*p*) communication
(*q*) government services
(*r*) miscellaneous services
(*s*) house property

The NCAER studies estimate the net outputs (or value added) of these sectors in every state. Thus, except for the mining sectors, these studies do not provide us with the required disaggregation of outputs for our endogenous sectors That forces us to go to the first hand sources of information for the manufacturing industries. Here again some special problems arise. Manufacturing industries in India are divided

13. "Distribution of National Income by States", 1960-61 by National Council of Applied Economic Research, New Delhi, January 1965.

into three broad categories: *e.g.*, (*i*) large scale, (*ii*) small scale, and (*iii*) household industries. These categories are defined according to the techniques of production and management scope of marketing, etc. Small scale and household industries in India are treated as exogenous sectors in our exercise on the ground that these industries essentially cater to the needs of the subsistence sectors of the rural Indian economy with their products, when marketed, going mainly to the local markets.[14] Hence, in a model for determining the optimal location of industries, these activities fall outside the decision variables of the system. But some of the products of these small scale sectors are closely substitutable with the products of the corresponding large scale sectors. For example, agricultural implements, metal products for household uses are manufactured both by the organized as well as the unorganized sectors of the economy. But again, the degree of substitutability is not perfect. In a very disaggregated model it might have been possible to distinguish between substitutable and non-substitutable products in some of the uses. In our case, a straightforward assumption is called for. Small industries are assumed not to compete with the large scale industries.

So, in our exercise, the 1960-61 levels of the "net output" of the various exogenous sectors are taken from the NCAER studies. The outputs of the three endogenous mining sectors are also taken from the same source.[15]

For the large scale manufacturing sectors, the main sources of information are the ten volumes of Annual Survey of Industries.[16] These annual surveys cover Indian large scale manufacturing industrial units which employ 20 or more workers and use power.[17] In the case of each produce (*i*) the number of existing firms in a state (*ii*) of which those who responded to the questionnaires (and hence included in the survey) and (*iii*) various economic statistics, *e.g.* production, sales, costs, capital, labor, relating to the respondent firms are recorded. From these statistics the annual production in 1960 of twelve separate industries are computed.

In forming the aggregates, the total production of any sub-industry

14. See Dhar and Lydall, "The Role of Small Enterprises in Indian Economic Development", Asia Publishing House, 1961.

15. "Annual Survey of Industries," 1960. Central Statistical Organization, New Delhi, in 10 volumes.

16. *Ibid.*

17. Only factories "which employ 20 or more workers on any day and use power" are registered under Indian Factories Act 1948.

in a state is obtained by dividing the total production of the respondents by the ratio of respondents to the total number of firms in the state,[18] and then adding up the outputs of these sub-industries, forming the above industry groups. On grounds of all available information, this seems to be an unbiased estimation procedure, because there is no way of knowing if the size of a firm is positively correlated with its propensity to respond to a questionnaire. However, it is worth remembering that these statistics are based on survey (rather than census) data and are subject to the usual estimating errors. Besides, the definition of large scale industries here is rather arbitrary as defined in the Factory Law. It may not correspond very closely to the economic classification (according to the technique of production, nature of market) we are interested in.

These estimates of state productions are now aggregated to national productions and compared with the initial conditions (also production levels in 1960-61) in the Manne-Rudra planning model,[19] because the sectoral classifications in the two exercises are more or less comparable. They are as follows :

	Value of Output in 1960-61 in Rs. Crores	
Manufacturing Sector	*Our Estimates*	*M-R Estimates*
Iron and Steel	242.15	269.0
Non-Ferrous Metal	38.77	32.0
Machinery	171.07	490.0
Transport Equipment	232.49	201.0
Electricity	69.23	103.0
Fertilizers	22.85	20.7
Other Chemicals	211.69	284.0
Textiles	944.20	930.0
Cement	61.19	53.0

It is seen that at least in the cases of two industries, namely electricity and machinery, the differences are very large.

In case of electricity, it is partly because the survey only includes the commerical electricity undertakings and excludes the production of electricity by the industrial firms generating for their own use.[20]. The

18. The ratio of respondents to the total number of firms lies between 84 and 100 per cent. In most cases the ratio is above 95 per cent.

19. "Studies in the Structure of the Indian Economy, "Report Number 5, Indian Statistical Institute, mimeographed, August 1964.

20. Out of the total 12976 MW of power capacity in India, 1446 MW were accounted for by self-generating units, see "Demand for Electricity," PPD, mimeographed, 1963.

final estimate of the production of electricity in a state in 1960-61, was obtained by adding to the previously obtained survey estimate a new estimate of correction, which was obtained by dividing the difference between Manne-Rudra estimate and our survey estimate in proportion to the estimates of state's supply of electricity in 1965-66, prepared by the Perspective Planning Division[21].

In the case of machinery, the states' production figures were blown up in proportion to add up to the Manne-Rudra estimate.

For the rest of the sectors, the survey estimates were retained.

Finally, the state statistics were aggregated to provide the initial conditions corresponding to the four regions.

Appendix B

The Statistical Bases of the Input-Output, Capital-Output and the Transport Coefficient Matrices

Input-Output Matrices

The major source of this coefficient is the 50-sector, "Inter-Industry Transactions Table of The Indian Economy, (At Market Prices)—1955-56" prepared by the Indian Statistical Institute, New Delhi. Except for Electricity, Textiles, and Sugar Industries, the coefficients derived from the above All-India transaction table were taken to represent the production coefficients for the various industries in each of the regions. For electricity, textiles and sugar sectors, a column of coefficients for each sector of each region was derived from the input transactions recorded in the Annual Survey of Industries, 1960. However, in the latter source the data did not always correspond to the sectoral classification specified in this model. In such cases, the input coefficients from those sectors in the All-India Table were scaled in proportion to the inputs from the corresponding group of sectors recorded in the Annual Survey to arrive at the respective regional coefficient.

An attempt was made also to construct the input-output coefficients for other manufacturing sectors in a similar manner from the Annual Survey volumes. But the coefficients so derived, showed a remarkable degree of interstate variance, which even after reasonable allowance is made for differences in the mix of products in the industry groups, difference in regional prices, etc., seem to be totally unrealistic. Besides,

21. *Ibid.*, Table 3, page 9.

various large scale manufacturing industries in different regions, particularly metallurgical and machine-building industries, normally have access to the same sorts of information, regarding technological possibilities, and normally show a great deal of similarity in the techniques of production.

In case of small scale industries, or services, no first sources of data were available to attempt any new estimation. For these sectors, the coefficients derived from the All-India transaction table of ISI were taken to represent the activities in different regions.

For the mining sectors, an alternative source of information is the set of regional studies by NCAER. But their estimates of mining expenses in different states[22] show such a remarkable degree of interstate invariance that one suspects that these were derived from some aggregate statistics. So, here again coefficients from the All-India table were used to describe the activities in various states.

In Table 3C, instead of input-output coefficient, input-value added coefficients are computed from the All-India table of ISI, because the productions in these aggregative sectors are measured in terms of the value-added.

Capital Coefficient Matrices

The major source of this set of capital-output coefficients is the Leontief B-matrix (for fixed capital investments) for the 50 sectors of the Indian economy corresponding to the "Inter Industry Transaction Table of the Indian Economy, 1955-56" of ISI, prepared at M. I. T. under the direction of R. S. Eckaus. However, an attempt was made to estimate these coefficients for different regions from the book-values of different categories of capital stocks of different industries in different regions recorded in the Annual Survey of Industries. But the results turned out to be totally inconsistent with any *a priori* notion of incremental capital-output ratios for the various sectors. That may be because

(*a*) The book values of capital stocks at historical costs taken as ratios of the current value of product need to be corrected for changes in prices, but for which the appropriate capital goods price indices and the data relating to the age of capital stocks were not available, or

(*b*) that the capital stock data of the survey are particularly unreliable. Anyway, except for agriculture and textile industries, the columns

22. NCAER, *op. cit.*, Tables 121-137.

of the above-mentioned All-India B-Matrix were assumed to describe the production processes of the various industries in all the regions alike.

For the agriculture sector, however, the regional differences in the capital output ratios are normally expected to be rather high[23]. Here, again, the capital coefficients for agriculture in the region were estimated by multiplying the All-India coefficients by the ratio of the over-all capital-output ratio for agriculture in the region to that of the whole country[24]. Considering the fact that the major non-labour input items in agriculture are fertilizers and irrigation (construction), which are exogenous in this model, this rather simple change of scale in the coefficients may not be altogether a bad assumption.

In the case of textile industries, which consist of important subgroups with different techniques of production, namely cotton textile, jute textiles, silk and other fibers, and since considerable differences exist in the mix of these industries in the regional pattern, a regional capital coefficient for this sector was obtained by a weighted average of the coefficients corresponding to the different subsectors ; the weights are proportional to the levels of production in 1960-61. It is assumed that over time the locational pattern of this group of industries, which is assumed exogenous in the model, will not change. This is not altogether a bad assumption, because jute industries are not likely to be established outside the eastern region, and given the souces of supply of cotton fiber, western and the southern regions are likely to retain their comparative specialization in this industry.

Transport Coefficients

These matrices had to be prepared fresh from primary sources, because no such attempt was made before to the best of the author's knowledge. For the purposes of estimating these matrices three sets of information are necessary : (*a*) the proper point estimation of a region, which is a geographical area, so that the distance between the two regions can be uniquely defined, (*b*) a proper definition of the unit of transportation so that a linear production function for that output, measured in that unit, does reflect the inherent economies of scale in long-distance haulage and (*c*) the average price per unit of weight (or some other characteristic determining the demand for transport services) of the output of various sectors.

23. See "Summing Up Pattern of Growth of States," NCAER, New Delhi. 1965.
24. *Ibid*, Table 11, page 26.

The point estimates of the regions were obtained by a visual study of the economic map of the country. These estimations are inherently crude, because there is no guarantee that the current center of gravity of economic activity of a region, if it were possible to decide accurately, would at all remain constant over time. Anyway, the estimates are as follows

(*i*) The distance between Regions I and II = 500 miles
(*ii*) The distance between Regions I and III = 1100 miles
(*iii*) The distance between Regions I and IV = 800 miles
(*iv*) The distance between Regions II and III = 500 miles
(*v*) The distance between Regions II and IV = 800 miles
(*vi*) The distance between Regions III and IV = 500 miles

However, these distances are fairly large compared to the average lead of goods traffic in Indian Railways, which is about 350 miles. And it is believed that marginal costs over additional distances, at higher lead fall very sharply. So, small misspecifications will not make substantial damages to the results.

The unit of transport output was taken at a rupee's worth of "competitive revenue" in 1960-61. The actual revenue of the Indian Railways, a state-managed enterprise, in 1960-61 was far short of what would be considered "competitive revenue", because of allegedly misguided considerations of keeping the freight rates low to promote greater flow of goods.[25] It was estimated that a competitive price for a ton of bulk commodity moved over the average lead, *i.e.* 350 miles, was Rs. 25.50, whereas the actual rate was about Rs. 18.60.[26] So, in this exercise, the units of transportation services of the various commodities over the specified distance were taken as the corresponding freight rates charged by the Indian Railway in 1960-61[27] multiplied by a factor of 25.50/18.60. It is worth mentioning that the actual rates show a large degree of telescoping the higher distances, as the rate per unit of distance falls as distance increases. It is assumed here that the rate-distance schedules of the Indian Railways do reflect correctly the real phenomenon of falling costs over distance, so that only a change of scale is sufficient to adjust the structure to true costs, which was referred to earlier as "competitive revenue."

25. See Lefeber and Datta-Chaudhuri, *op. cit.*, Chapter II.
26. *Ibid.*, Chapter III.
27. "The Report of The Railway Board," Book II. 1960, The Ministry of Railways, Government of India.

As regards value-weight ratios for various commodities, coal and iron ore being relatively homogeneous do not present any problem. But for the other metallurgical products the following price approximations were assumed

Iron and steel	Rs.	675 per ton
Non-Ferrous Metals	Rs.	1,800 per ton
Machinery and Transport Equipment	Rs.	2,000 per ton

The first two figures were taken from the average prices of these metal products, assumed in the Perspective Planning Division Studies, and in the third case it was assumed that the value-weight ratios of these products are similar to that of the average category of special steels used in India, and as used in the same study.[28]

In the case of electricity transmission, however, these considerations do not come into play. In this exercise, interregional transportation is taken as one single activity and its production coefficients are taken to be those of the railway. However, the nature of electricity transmission is different; but in this study the regions are taken to be so large that in any optimal program not much of interregional transmission of electricity would be considered optimal. So, instead of defining a new activity for the transmission of power, the money costs of transmission over the specified distance is taken as the units of transportation for the sector; and it is assumed that the production function for the railway would not be exceedingly different from this activity, once its outputs are measured in terms of real costs. The cost items are taken from Jaleel Ahmad's study on electricity generation and transmission in India.[29]

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28. "A Preliminary Study on Unit Consumption Data", by Perspective Planning Division, Planning Commission, 1961.
29. See, Ahmad, J., "Rural Electrification in India," Ph.D. Thesis, M.I.T., 1965.